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# GEOTECHNICAL CONSIDERATIONS FOR THE DESIGN OF THE EXTENDED FLY ASH MOUND AT NANTICOKE TGS

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## ABSTRACT

By switching from the currently used wet ash disposal method to a dry ash disposal method at the Nanticoke TGS, the areas where the existing ash settling cells and part of the primary lagoon are located, can be reclaimed and used for future ash storage. This conversion in the ash disposal method will increase the ash storage capacity of the existing facility by about 70%, which is equivalent to an additional storage life of 9-1/2 years.

In this report, a conceptual design for the proposed extension of the existing ash storage mound to be located on the reclaimed area is presented.

In this design, the advantage of stage construction is fully utilized. The performance of the ash storage mound constructed during Stage 1 and Stage 2A will be monitored and the results will be used to ensure the performance of the future ash storage mound.



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# GEOTECHNICAL CONSIDERATIONS FOR THE DESIGN OF THE EXTENDED FLY ASH MOUND AT NANTICOKE TGS

## 1.0 INTRODUCTION

Nanticoke TGS is one of the world's largest coal-fired generating stations. It consumes some six to eight million tonnes of coal per year, producing six to seven hundred thousand tonnes of coal ash which must be properly managed. Currently, a wet ash disposal method is being used at the site (Fig. 1). The ash disposal facility, which consists of lagoons, ash settling cells and the permanent ash storage area, covers approximately 77 hectares of land and is enclosed by a perimeter clay dyke rising about 10 m above the surrounding terrain.

In the currently used wet ash disposal method, the fly ash from the boilers of the generating station is transported as a slurry in a pipeline and is first deposited in the settling cells. When the cells become full, the ash is dredged and is loaded into trucks and then dumped at the permanent storage area. It is estimated that the present ash storage capacity will be used up by year 1996.

Currently, Ontario Hydro is searching for more ash storage area for the Nanticoke TGS. At present, an area of about 50 hectares on the east side of the existing ash storage facility is being considered as one of the possible future ash storage sites (Figure 2). In addition, a future ash storage area to be reclaimed from the existing ash storage facility due to switching from the currently used wet ash disposal method to the dry ash disposal method is being considered. The dry ash disposal method will increase the storage volume of the existing ash storage facility by about 70%, which is equivalent to an additional ash storage life of about 9-1/2 years.

In this report, a conceptual design for the extension of the existing ash storage mound is presented.

## 2.0 EXISTING SITE CONDITIONS AND HIGHLIGHTS OF THE PROPOSED RECLAMATION CONCEPT

The currently used wet ash storage facility (Figure 2) which occupies an area of 77 hectares is enclosed by a perimeter clay dyke sitting on a natural clay formation. The crest of the clay dyke is about 10m above the surrounding terrain. Within the perimeter clay dyke, there are 4 primary settling cells, 3 secondary settling cells, one primary lagoon, one secondary lagoon and a permanent ash storage area. The permanent ash storage area is located on the southeast corner of the ash storage facility.

Ash from the boilers of the generating station is mixed with water into a very thin slurry and pumped to the settling cells. When the cells become full, the ash is dredged and is loaded into trucks and then placed on the long-term ash storage area. The design cross-sections of the long-term ash disposal mound are shown in Figures 3, 4, and 5. The final crest elevation of the ash mound is at 212.2 m (696′) which is 15.2 m (50′) above the crest of the perimeter clay dyke.

The two 6.1 m (20′) high ash berms sitting on top of the existing ash storage mound are designed as wind barriers to control the dust problem at the site (Figure 2).

Surface runoff from the ash storage mound is intercepted by a perimeter ditch drain around the existing ash storage mound and is drained to the primary lagoon located on the northeast corner of the storage facility. The north dyke, which separates the existing ash storage mound from the primary lagoon, was constructed of slag and bottom ash. Such a design renders the north dyke to be quite permeable and water in the ash mound can flow easily to the primary lagoon.

During the construction of the ash storage mound, the dust problem at the site is being controlled by means of spraying water and/or chemical agent on the exposed fly ash surface during dry and windy periods. Furthermore, the construction sequence of the ash storage mound is being planned such that prior to the ash placement operation, two higher ash berms will have been constructed on the southwest and northwest sides of the long-term ash storage area. The elevation of the berms is being maintained at 12.2 m (40′) above the rest of the ash disposal area. These ash berms are used as wind barriers.

With the present wet ash disposal method, the ash storage facility is estimated to reach its full capacity by the year 1996.

Recently, Ontario Hydro decided tentatively to switch the currently used wet ash disposal method to a dry ash disposal method. In the proposed dry ash disposal method, water will be added to the dry ash from the boilers to reach a moisture content of about 15% (moisture content is defined as weight of water to the weight of dry ash). The ash will be transported to the ash storage area by trucks. The ash will be spread and lightly compacted by a bulldozer. By switching to the dry ash disposal method, part of the existing settling facilities within the ash storage site will no longer be necessary and the land occupied by these settling cells will be reclaimed for additional ash storage.

In Figure 6, a comparison between the extent of the ash storage mound constructed under the proposed dry and the currently used wet ash disposal methods is presented. It is estimated that by switching from the wet ash disposal method to the dry ash disposal method, an additional 9-1/2 years of ash storage life can be obtained.

The ash placement scheme proposed by the Civil Design Section of the Civil Engineering and Architecture Department consists of 4 stages. The layout of each ash placement stage is presented in Figures 7, 8, 9 and 10. The storage volume of each placement stage is listed in Table I. Stages 2C, 3A and 4A which involve the filling at the proposed East site ("E" site) will not be discussed in this report.

Stage 1 of the placement scheme involves the filling of the existing ash storage mound to elevation 210 m (689'). In Stage 2A, the existing ash storage mound will be filled to its final level. During Stage 2B of ash placement, the area where the primary ash settling cells #3 and #4 is located will be reclaimed and used for ash storage.

In Stage 3B, the existing ash storage mound will be extended in the northern direction and the ash storage area is mainly reclaimed from the primary lagoon. The remaining portion of the lagoon shown in Figure 9 will be used as the runoff retention pond.

Stage 4B involves the filling of the area west of the existing ash mound. During this stage, the area where the primary ash settling cells #1 and #2 is located will be reclaimed and used for ash storage.

In Stage 4C, the existing ash mound will be extended in the west direction. During this period, the secondary ash settling cells will be reclaimed.

In the proposed dry ash disposal method, the moisture content of the ash is relatively lower than the moisture content of the ash produced by the wet ash disposal method. The lower moisture content of the ash may aggravate the dust problem. Thus, in the conceptual design of the new ash disposal area, special attention is given to the dust problem.

In a previous study/1/, it was determined that the stability of the slope of the ash storage mound is very sensitive to the groundwater level within the ash storage mound. Therefore, during the construction of the proposed extension of the ash storage mound, surface runoff drainage systems are incorporated in the design to reduce the amount of infiltration into the ash mound. At the close out stage of the storage facility, a final cover is designed to reduce the rate of surface water infiltrating into the ash mound. With the reduction in infiltration into the ash mound, the level of groundwater pressure build-up within the ash mound will be minimized and the amount of leachate seeping out from the site will be reduced.

## 3.0 CONCEPTUAL DESIGN

In the design of the proposed ash mound extension, the following potential problems may affect the performance of the proposed ash mound extension. They are listed as follows:

1. Slope instability due to the slope geometry.
2. Dust problem caused by wind.
3. Serviceability of the roads caused by water ponding during construction.
4. Groundwater pressure and leachate caused by surface infiltration.
5. Slope instability caused by the contact zone between the existing ash mound and the proposed extension.

These potential problems are addressed in the following sub-sections.

### 3.1 Slope Geometry

In the existing design, the elevation of the crest of the ash storage mound is 212.19 m (696′) which is 15.2 m (50′) above the crest of the perimeter clay dyke that encloses the ash storage facility. The side slope of the existing ash storage mound is 3 (horizontal):1 (vertical). Extensive slope stability calculations have been performed to determine the stability of the slope of the existing ash storage mound/1/. Based on the previous calculations, it is suggested that the side slope of the proposed ash mound extension also be 3 (horizontal):1 (vertical). In the design of the proposed ash mound extension, the final elevation of the crest of the mound is at 218.2 m (716′), which is 6.1 m (20′) above the final crest elevation of the existing ash mound. Thus in this report, a slope stability analysis is performed to evaluate the proposed slope geometry design.

In order to increase the storage capacity of the remaining retention pond, it is proposed that the elevation of the crest of the proposed retention dyke will be at elevation 196.9 m (646′) which is the elevation of the crest of the perimeter clay dyke. A slope stability analysis is conducted on section a-a shown in Figure 1. Owing to the fissured nature of the weathered clay layer beneath the ash storage facility, the effect of the variation in the shear strength of the clay layer on the stability of the slope is investigated. The results of the study are tabulated below:

| | Assumed Friction Angle of the Clay | | | |
|---|---|---|---|---|
| groundwater level (Figure 11) | $15^0$* | $20^0$ | $25^0$ | |
| 203.29 m( 667′) | 1.004 | 1.20 | 1.287 | } safety factors |
| 197.19 m( 647′) | 1.069 | 1.269 | 1.347 | |
| 189.27 m( 621′) | 1.147 | 1.353 | 1.425 | |

*the residual frictional angle of the weathered clay.

The results indicate that with the use of the residual friction angle of the weather clay, the stability of the slope is marginal.

It is felt that the use of the residual frictional angle ( $15^{o}$) in this analysis is not appropriate because this lower bound value should be used in the design of slopes due to excavation. With the continuing placement of ash, the loading due to the weight of the ash will consolidate the clay and the shear strength of the clay will increase. If the water level within the mound can be controlled at or below elevation 197.2 m (647'), the slope will have a safety factor above 1.27, which indicates that the design cross-section shown in Figure 11 is acceptable. The use of a higher frictional angle for the design may be further justified by a piezocone testing program to be performed at the site in the future.

The results of the above analysis indicate that the stability of the slope sections is sensitive to the location of the groundwater level. At present, the groundwater level of the existing ash mound is being monitored by piezometers and the results will be used to ensure the design of the side slope of the proposed ash storage mound extension.

In the new ash mound design, the crest of the mound is at 33.5 m (110') above the bottom of the retention pond. Because of the great height of the mound, erosion of the slope surface by surface runoff will be critical. It is therefore proposed that benches with interceptive drains should be provided on the slope. The benches should be slightly inclined downwards towards the slope in order to maximize the efficiency of the interceptive drains (Figure 12).

In order to integrate the slope geometry of the proposed extension to the existing ash mound, a bench of 10 m (32,8') wide is provided on the side slopes of the new ash mound at elevation 212.1 m (696'). Toe drains (Figure 13) which consist of slag and are protected by geotextile are suggested for the proposed extension. Such drains will provide a means to control the groundwater level within the mound which in turn will improve the stability of the slope. This type of drain is especially effective in improving the sloughing type surfacial slope failure.

### 3.2 Dust Control - Cells and Wind Barriers

The dust problem increases with a larger exposed fly ash surface to wind. By constructing the ash mound in small cells, the area exposed to wind will decrease. In this study, it is proposed that during each ash placement stage, the storage area will be divided into small cells. Each cell has an area of 0.5 hectares and a 2.5:1 side slope. When the cell is filled to a thickness of 5 m, a 0.2 m thick layer of slag or bottom ash may be used to cover the ash surface and the ash placement operation will be switched to the next cell. One of the functions of the slag layer is to reduce the dust problem caused by wind. In addition to the slag cover, a wind barrier is proposed to control the dust problem at the site. The results of the wind tunnel model tests conducted by Morrison Hershfield Limited on the existing ash mound indicate that a wind barrier is one of the most effective means for controlling the dust problem/2/. In this study, the critical wind directions at the site are determined to be from the west and northwest. It is proposed that during each stage of the ash storage mound construction, an ash berm will be constructed to the northwest of the ash storage area prior to the placement of ash in the cells behind the berm.

It is known that the stability of the ash mound is highly dependent on the groundwater level within the mound. Therefore, in this design, the crest of each cell will be graded to provide surface drainage such that the amount of infiltration into the ash mound will be minimized and the occurrence of a ponding condition which could damage the serviceability of roads can be eliminated.

### 3.3 Contact Zone Between the Existing Ash Storage Mound and the Proposed Extension

In this design, special attention should be given to the contact area between the existing ash mound and the proposed extension. The surface of the side slope of the existing ash mound is constructed of a thin layer of topsoil covered with grass. This organic layer would create a weak shear zone which could reduce the stability of the new ash mound. This zone could form a permeable zone as shown in Figure 14, which could be filled with water and create an adverse hydraulic condition to the stability of the mound. It is proposed that at the contact zone, the vegetation on the existing ash slope will be stripped prior to the construction of the ash mound extension. The stripped vegetation may be replanted in an area where it is required. An internal drain (Figure 15) constructed of gravel or slag, which is protected by geotextile, should be constructed at the toe of the existing slope. At the close-out stage of the ash storage mound, the internal drain incorporated with the permeable zone at the existing slope forms a chimney drain which is extremely effective in controlling the potential buildup of pore water pressure within the mound. The water collected from the internal drain will be discharged to the retention pond through the perimeter ditch drain (Figure 16).

### 3.4 Drainage

A drainage system is required both during construction and after the close-out stage of the ash mound. During construction, a good drainage system will provide a good working environment, an effective compaction effort and a reduction in the amount of infiltration into the ash mound. This in turn will decrease the groundwater pressure within the mound. After the closing-out of the mound, a good surface drainage system will reduce the amount of infiltration into the mound and the amount of leachate seeping out of the ash mound.

#### 3.4.1 During Construction

In this conceptual design, it is proposed that during each construction stage, the surface of the cells will be properly graded. The grading will provide natural drainage of the surface runoff from the cells. The water will be collected in a temporary drainage ditch and disposed of to the runoff retention pond (primary lagoon). The layout of the wind barriers, the cell systems and the temporary drainage ditch for each construction stage is presented in Figures 17, 18, 19 and 20. A cross-section of the temporary drainage ditch is presented in Figure 21. At the completion of each stage of construction, the top of the ash mound will be properly graded and drained to the perimeter drainage ditch located at the crest of the ash mound. Such a drainage system will reduce the amount of infiltration into the mound. The

reduction in the amount of surface runoff on the side slope of the mound will minimize surface erosion of the slope. The layout of the perimeter drainage ditch at the crest of the ash storage mound for each construction stage is presented in Figures 22, 23, 24 and 25.

### 3.4.2 At Close-Out Stage

At close-out, the perimeter drainage ditches at the top of the ash mound from the different construction stages will be integrated into a single drainage system. The layout of the drainage system is presented in Figure 25. The surface runoff intercepted by this drainage system will be discharged to the lake through drain pipes. The design of the perimeter drainage ditch is shown in Figure 26. The water collected by the toe drains and the internal drains will be discharged directly to the perimeter ditch drain and subsequently to the retention pond for monitoring.

## 3.5 Proposed Retention Dyke - Stability Due to Water Drawdown

With the dry ash disposal method, part of the existing primary lagoon will be used for ash storage and the remaining part of the lagoon will be used as a retention pond.

At the close-out stage of the proposed ash storage mound, runoff from the toe drains and internal drains within the ash storage mound will be discharged to the runoff retention pond for monitoring. If the water quality does not meet environmental requirements, it will be treated at the new effluent waste treatment facility prior to discharge into the lake. If the water quality satisfies the requirements, then the water will be discharged directly to the lake and the runoff retention pond can be eliminated.

The design of the proposed retention dyke is shown in Figure 27. In the proposed design for the retention dyke, the crest elevation of the dyke will be raised to 196.9 m (646′). The stability of this dyke has been determined in Section 3.1. The results indicate that the stability of the mound depends on the groundwater level within the mound. Additional stability calculations have been performed due to possible drawdown conditions. These conditions are listed as follows:

1. During Stage 3 of the ash placement schedule, the existing primary lagoon may be dewatered for the construction of the proposed new retention dyke and the placement of ash in the reclaimed area.

2. At close-out, if the quality of the water from the toe drains and the internal drains satisfies the MOE requirement and is being discharged directly into the lake, the water level within the retention pond can be lowered. The lowering of the pond level will promote drainage of the water within the ash mound (if it exists) to the retention pond.

The effect of lowering the retention pond water level on the stability of the dyke are twofold:

1. An increase in stability due to the lowering of the groundwater level within the slope.

2. A decrease in stability due to the reduction in pond water level (the water in the pond provides a resisting force against slope failure).

When the rate of drawdown of the lagoon is too fast, failure of the slope may occurr. The factors of safety of the slope through controlled drawdown conditions are listed below:

| | Assumed Friction Angle of Clay | | |
|---|---|---|---|
| | $15^0$ | $20^0$ | $25^0$ |
| Moderate rate of drawdown | 1.066 | 1.304 | 1.523 |
| Slow rate of drawdown | 1.147 | 1.398 | 1.63 |

The locations of the phreatic surface used for the calculation of the drawdown condition are shown in Figure 27. The results of this stability analysis indicate that the design of the new retention dyke is acceptable. In this conceptual design, a drawdown rate of 25 mm per day is proposed. During the dewatering operation, the pore water pressure within the new retention dyke, the perimeter clay dyke and the ash mound should be monitored in order to calibrate the proposed drawdown rate and to ensure the safety of the operation.

An alternative to the construction of the proposed new retention dyke is to use the existing secondary lagoon as the future runoff retention pond. If the ash in the existing primary lagoon area is being placed under water, then no dewatering of the primary lagoon is needed. This option will increase the ash storage volume and save the cost on the construction of a new retention dyke.

The feasibility of using this alternative depends on the amount of runoff to be retained in the secondary lagoon. At present, it is anticipated that the amount of water requiring treatment can be reduced by providing the ash mound with a properly designed final cover.

### 3.6 Foundation Treatment

During the placement of ash on the reclaimed area, a foundation treatment in areas where soft foundation zones may be located is required. In the ash placement Stages 2 and 4, the reclaimed area involves the existing settling cells. It is proposed that all the soft ash within the settling cells should be removed and the water within the cells be drained. The cells will be backfilled with dry ash. If the water level within the cells cannot be pumped down, the cells will be backfilled with a more competent material such as bottom ash, slag or imported granular materials.

Stage 3 involves the filling of a portion of the primary lagoon and the construction of the proposed new retention dyke. According to a study in 1988, the thickness of the fly ash deposit at the bottom of the lagoon ranged from 3 m in the west of the lagoon to 0.0 m in the east of the lagoon.

If the lagoon is dewatered prior to the construction of the proposed new retention dyke and the placement of ash, the soft ash layer can be stripped and stockpiled for future ash placement.

Furthermore, the clay layer at the bottom of the lagoon has been exposed to water for years. Swelling and or chemical changes of the clay may reduce the shear strength of the clay. It is recommended that after dewatering of the lagoon, the clay formation be examined and the soft layer be removed. The stripped soft clay layer should be stockpiled for the construction of the final cover and the impermeable base of the perimeter drainage ditch.

If the ash mound and the proposed new retention dyke are being constructed underwater, foundation treatment by underwater dredging will be extremely tedious. An alternative to this approach is to improve the shear strength of the foundation materials by stage loading. The existing shear strength and properties of the soft ash and the clay layer under the lagoon can be determined by both field and laboratory testing. Stage loading of the clay will be performed in a trial area within the lagoon. The increases in shear strength of the soft ash and the clay layer with time will be monitored. These results will be used to design an ash placement schedule, which will ensure the stability of the ash mound.

### 3.7 Monitoring

The objectives of a monitoring program at the site are as follows:

1. To ensure the groundwater level within the ash mound does not rise to a level that could endanger the stability of the ash mound.

2. To ensure the proper performance of the disposal system.

3. To provide data for the evaluation of the final cover.

At the end of the Stage 2A, it is proposed that two nests of piezometers will be installed in the mound. Each piezometer nest will consist of 5 piezometers. The proposed locations of the two strings of piezometers are shown in Figure 28. The vertical layout of the piezometers are shown in Figure 29. Geonor standpipe type piezometers are proposed to be installed at this site because with other types of standpipe piezometers, the possible caving of the ash into the borehole makes it extremely difficult to seal the annulus space between the borehole wall and the standpipe of the piezometers. The functions of the piezometers are to determine the groundwater pressure within the ash storage mound and the hydrogeological performance of the facility.

The amount of infiltration into the ash mound will be monitored by two Agwa sensors installed beneath the cover of the ash mound. The measured results from the Agwa sensors will provide information on the performance of the cover provided at the site. If the results from the monitoring program indicate that the existing cover is not adequate, then a more expensive cover, as recommended in the following section, should be considered.

With the completion of Stage 2B of ash placement, one additional nest of piezometers will be installed in the ash mound (Figure 28). This nest of piezometers will provide more information on the groundwater pressure regime within the ash mound constructed with the dry ash disposal method.

The performance of the facilities will be monitored by obtaining water samples from piezometers located both within and outside of the ash storage facility.

3.8 Final Cover Design

The main function of the final cover at the site is to limit the amount of infiltration into the ash mound. With an increase in the amount of infiltration into the mound, the groundwater level within the mound will increase. Such an increase in water level will subsequently decrease the stability of the mound and increase the amount of leachate seeping out of the storage facility through the bottom of the ash mound. Therefore, the design of the final cover should be considered carefully.

With the present wet ash disposal method, the settling cells and the lagoons within the disposal facility are filled with water to elevation 195 m (640') and 189.3 m (621') respectively.

With the close-out of the facility, the final cover on top of the mound will reduce the amount of water infiltrating into the mound and subsequently decrease the rate of leachate seeping out of the facility through the clay barrier. It has been suggested that the present water quality of the groundwater at the site be monitored. The results will provide the upper bound values of the leachate quality to be encountered at the site. Based on the water quality values measured at the site and the the allowable values imposed by the MOE, a final cover will be selected/3/.

At present it is proposed that at the end of Stage 2A construction, the crest of the mound will be covered with the selected final cover. The performance of this cover will be monitored by the piezometers and the Agwa sensors installed in the mound. The results of this monitoring program will provide important information on the efficiency of the selected cover. If the existing cover fails to perform as required, the following final covers could be considered. In the selection process, the availability of construction materials, the cost and the construction procedures involved should be considered.

A. Bottom Ash Cover

This cover option consists of 150 mm of topsoil over 0.5 m of bottom ash. The surface of the cover will be vegetated. The surface runoff on the crest of the ash mound will be drained by proper grading of the top of the mound, and will be intercepted by the perimeter drainage ditch on top of the mound. The water from the top of the mound is assumed to be clean and will be discharged directly to the lake through downslope drainpipes and drainpipes located outside the perimeter clay dyke.

Water collected off the slope, from the internal drains and toe drains, is drained through the perimeter ditch drains to the runoff retention pond for monitoring. If the water quality satisifies the MOE requirements,it will be discharged directly to the lake. Otherwise, the water will be pumped to the new effluent waste treatment building for treatment.

It is proposed that this cover option be installed on the existing ash mound. The performance of this cover will be monitored by both piezometers and Agwa sensors. The results from this monitoring program will provide important information for the selection of a final cover for this site.

B. Complete Clay Cover Option

This option of final cover is suggested by Golder Associates as one of the candidate final covers for the Eastern ash disposal site/4/.

It consists of 150 mm of topsoil, over 0.85 m of general fill, over 0.5 m of a clean filter/drain sand (obtained off site), over a 0.6m thick compacted clay cover. All runoff is collected in the perimeter ditch drain and conducted to the runoff retention pond for monitoring.

In addition to the above design, it is proposed that the top of the ash mound be properly graded to drain to the perimeter drainage ditch on top of the ash mound and be seeded to minimize erosion.

C. Complete Geomembrane Cover Option

This cover option is designed by Golder Associates as a candidate for the final cover for the Eastern "E" ash disposal site. The cover consists of 150 mm of topsoil over a geotextile, over 0.5 m of filter sand (obtained off site), over a 40mil HDPE liner, over 0.5 m of bottom ash bedding. On the slopes, the HDPE liner should be 60 mil thick and it must be textured to prevent sliding. All runoff will be collected in the perimeter ditch drain and will be conducted to the runoff collection pond for monitoring and discharge.

Prior to the selection of this option as the final cover, the following points should be reviewed:

1. The placement and compaction of the sand layer over the HDPE liner may be difficult to achieve.

2. The interface shear strength between the HDPE liner and the bottom ash (or the filter sand layer) should be determined and the possibility of sliding failure of the liner should be checked, because a residual friction angle of $8^{o}$ has been determined for the interface between an HDPE liner and a clay soil.

For estimation purpose, it is assumed that option A will be selected as the final cover. It is felt that with proper surface drainage at the top of the mound, the amount of water available for infiltration will be minimized. In

addition, the evapotranspiration process of the vegetation on the cover will further reduce the amount of water available for infiltration into the ash mound.

## 4.0 CONSTRUCTION SCHEDULE

The construction schedule for the different construction stages can be generalized into the following steps:

1. Foundation preparation, construction of perimeter ditch drain and toe drains.

2. Construction of wind barrier - ash berm.

3. Construction of temporary drainage ditch - to intercept the surface runoff from the the ash cells.

4. Placement of ash cells. Repeat steps 3 and 4 until the mound reaches its final elevation.

5. When the crest of the ash mound reaches its proposed final elevation, the top of the ash mound will be graded and the final cover will be constructed.

6. Construction of a perimeter drainage ditch at the crest of the ash mound to intercept the surface runoff.

7. Monitor the performance of the mound - groundwater pressure within the mound and the effluent from the mound.

For construction Stages 1, 2A and 2B, no foundation treatment is anticipated. For Stage 3 and 4A which involve the reclamation of the settling cells and a portion of the primary lagoon, the foundation preparation recommended in section 3.6 should be followed.

During construction Stage 2B, 3 and 4A, the contact zone between the existing ash mound and the proposed extension should be treated according to the recommendation given in Section 3.3. The treatment of the contact zone involves the stripping of the vegetation on the existing ash mound and the provision of an internal drain at the toe of the existing ash storage mound.

## 5.0 SUMMARY AND DISCUSSION

By switching from the currently used wet ash disposal method to the dry ash disposal method, the area where the existing ash settling facilities are located can be reclaimed and used for future ash storage.

In order to integrate the slope geometry of the proposed extension with the existing ash storage mound, a side slope of 3 (horizontal):1 (vertical) is selected for the proposed extension. The stability of the proposed slope is considered acceptable. Since the stability of the slope is very sensitive to the groundwater level within the ash storage mound, the groundwater pressure within the mound will be monitored to ensure the stability of the mound.

In order to control the dust problem at the site, prior to each ash placement stage, an ash berm will be constructed on the northwest side of the storage area. This berm will act as a wind barrier. Ash will be placed in cell units of 0.5 hectares in area. When it reaches a thickness of 5 m, the surface of the cell will be covered with 0.2 m of slag. The top of the cell will be graded to enhance drainage and reduce infiltration.

The new retention dyke which forms part of the runoff retention pond has a slope of 3:1 and a crest elevation at 196.9 m (646').

In order to ensure the stability of the slopes, any drawdown operation within the runoff retention pond should be controlled and the groundwater pressure within the slopes around the runoff retention pond should be monitored.

At the completion of Stage 2A (completion of the existing ash storage mound), the existing ash mound will be monitored. The results will be used to evaulate the performance of the ash storage mound and the final cover.

At present, for preliminary cost estimate purposes, a final cover which consists of 0.2 m of vegetated topsoil over 0.5 m of bottom ash is proposed. The crest of the mound will be graded and perimeter drainage ditch will be provided to intercept surface runoff. This design will reduce the quantity of water required to be treated, the amount of infiltration into the mound and surface erosion at the slope caused by surface runoff.

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2. Lepage, M.F. and Davies, A.E. 1986. " Dust Control Study for the Nanticoke TGS Fly Ash Lagoon, Nanticoke, Ontario". Morrison Hershfield Limited Consulting Engineers, Report No. 48516181.

3. Heystee, R. J. 1989. Private Communication.

4. Golder Associates Ltd. 1989. "Conceptual Design - Dry Ash Disposal Facility - Nanticoke Thermal Generating Station, Walpole Township, Ontario". Project No. 881-1823.

## TABLE I

### Ash Storage Volumes

| Ash Piling Stage | | Ash Volume ($10^6$ $m^3$) |
|---|---|---|
| 1 | 1988-94 | 2.730 |
| 2A | 1995-97 | 1.719 |
| 2B | 1998-99 | 1.174 |
| 2C | 2000-02 | 1.457 |
| 3A | 2003-06 | 2.143 |
| 3B | 2007-09 | 1.644 |
| 3C | 2010 | 0.562 |
| 4A | 2011-12 | 1.060 |
| 4B | 2013-14 | 1.150 |
| 4C | 2015 | 0.59 |

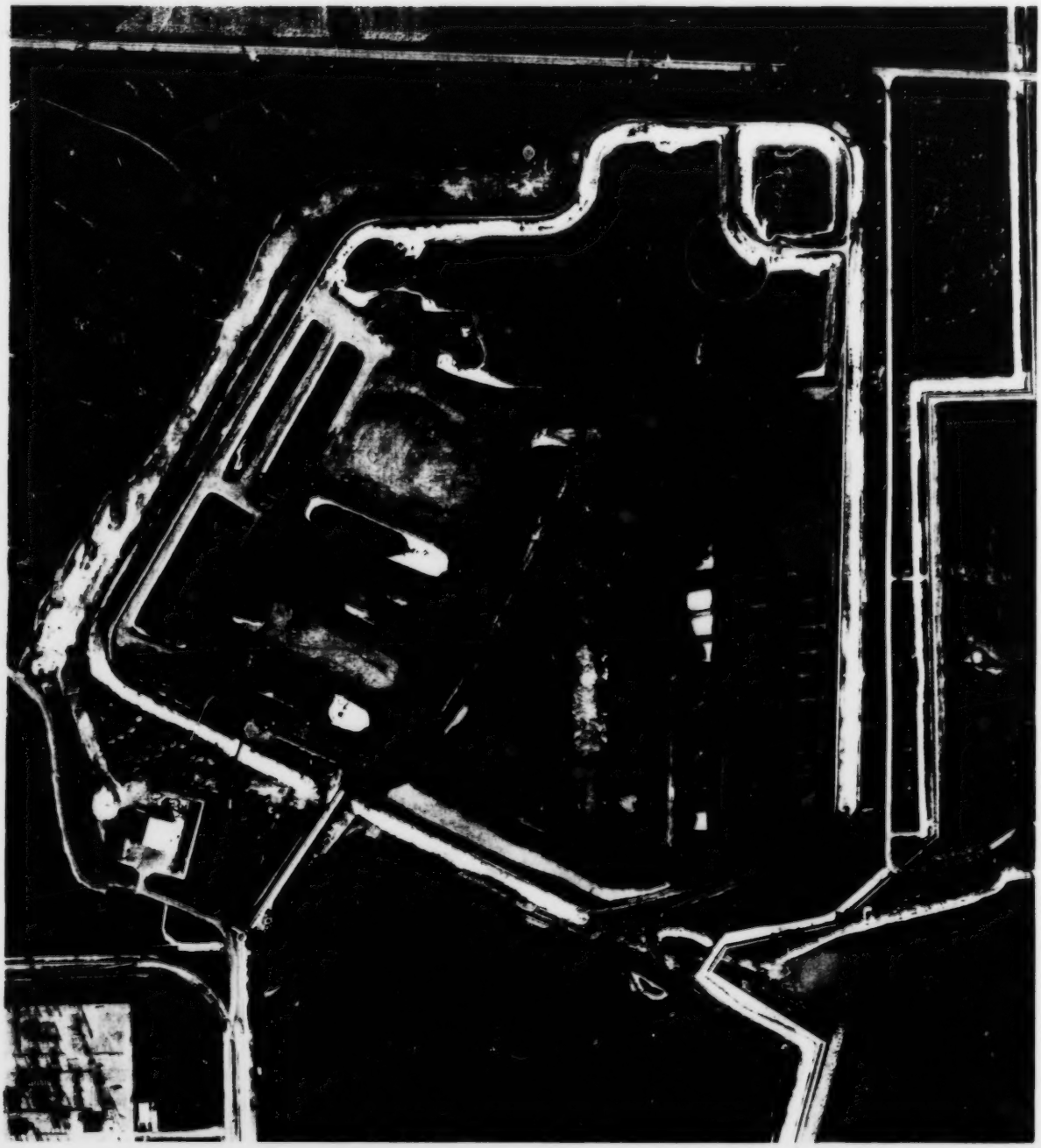

FIGURE 1

AERIAL PHOTO OF NANTICOKE TGS ASH LAGOON (1988)

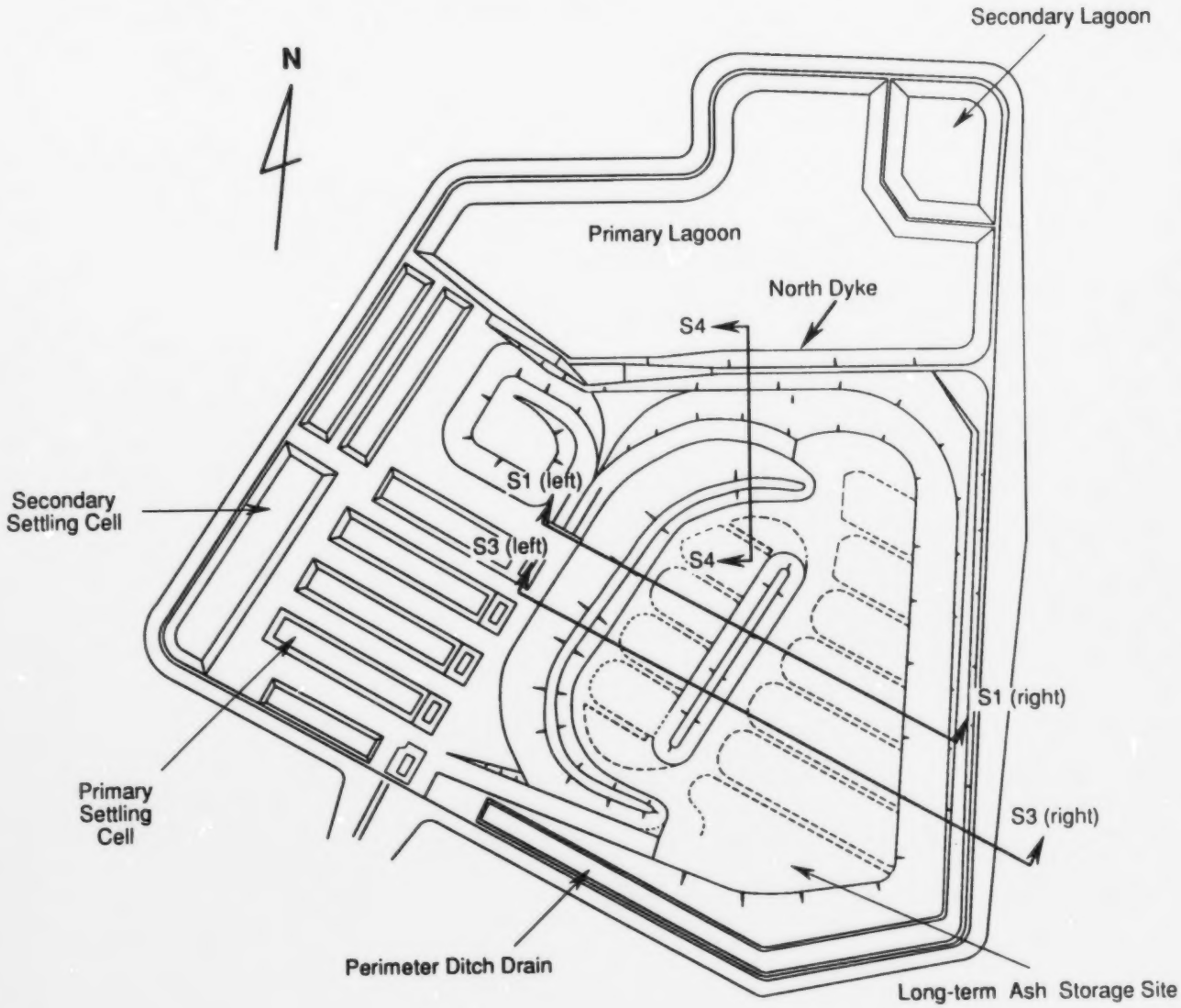


**FIGURE 2**

**PLAN VIEW OF THE EXISTING ASH STORAGE MOUND**

180720-C11-RD

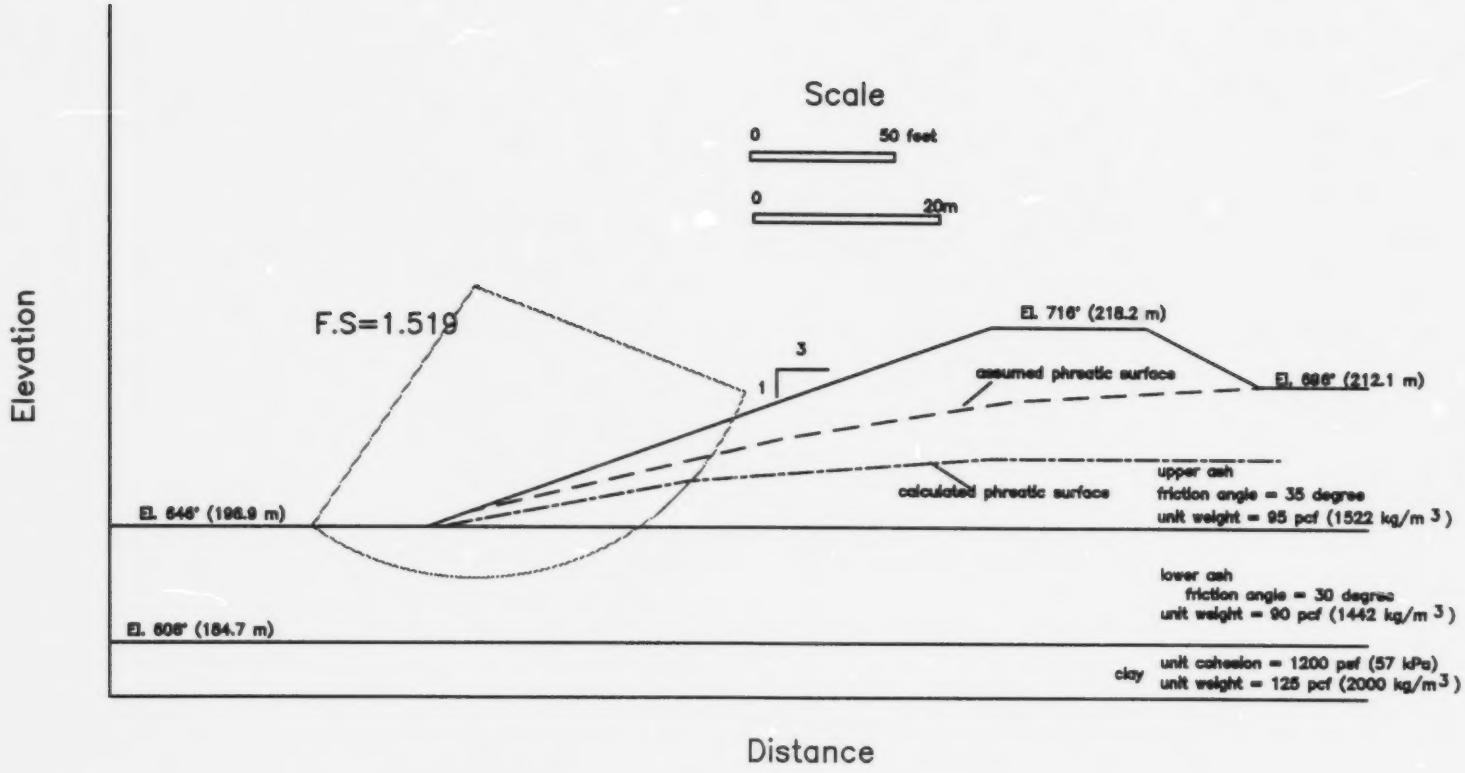


Figure 3 Design cross section of the existing ash storage mound – Section S1 "left side".

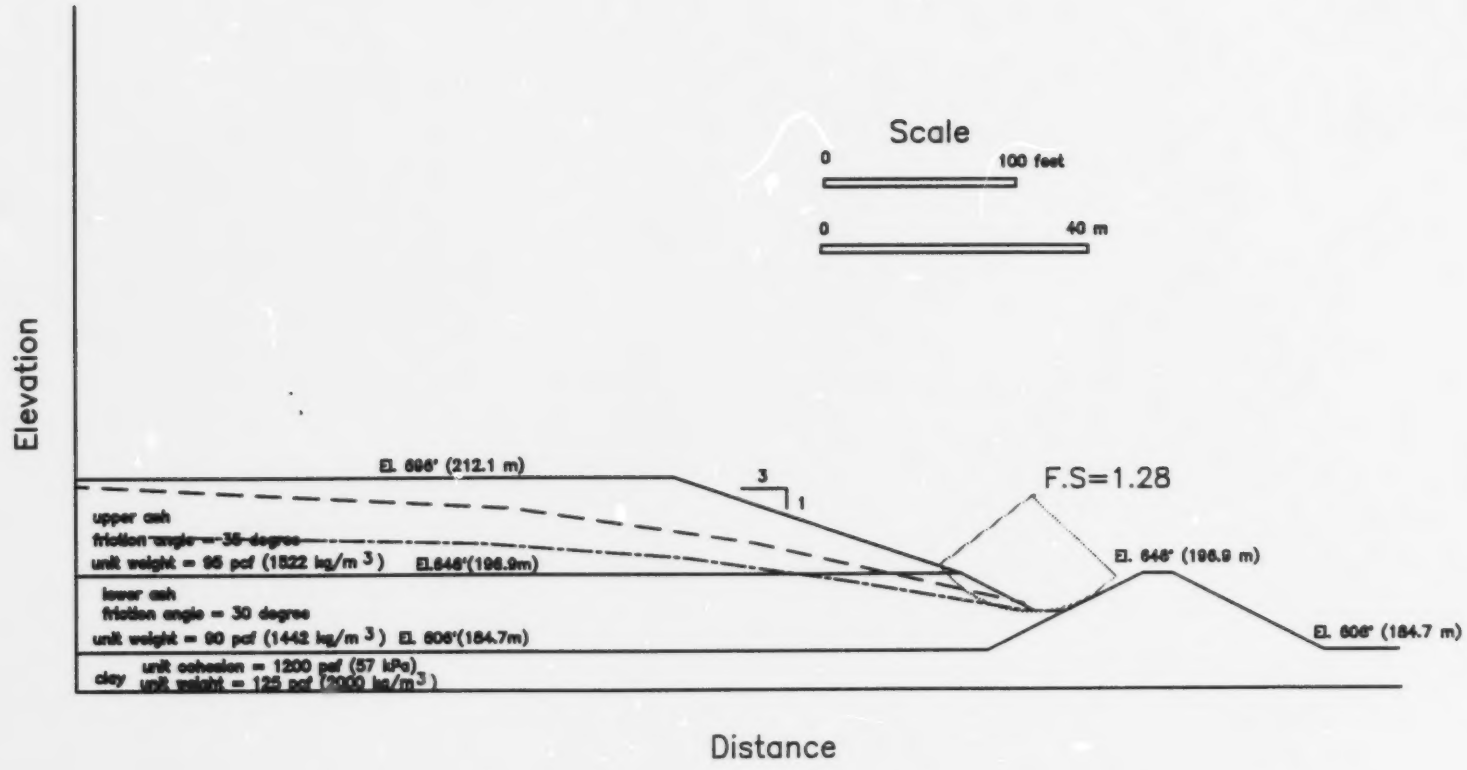


Figure 4 Design cross section of the existing ash storage mound – Section S3.

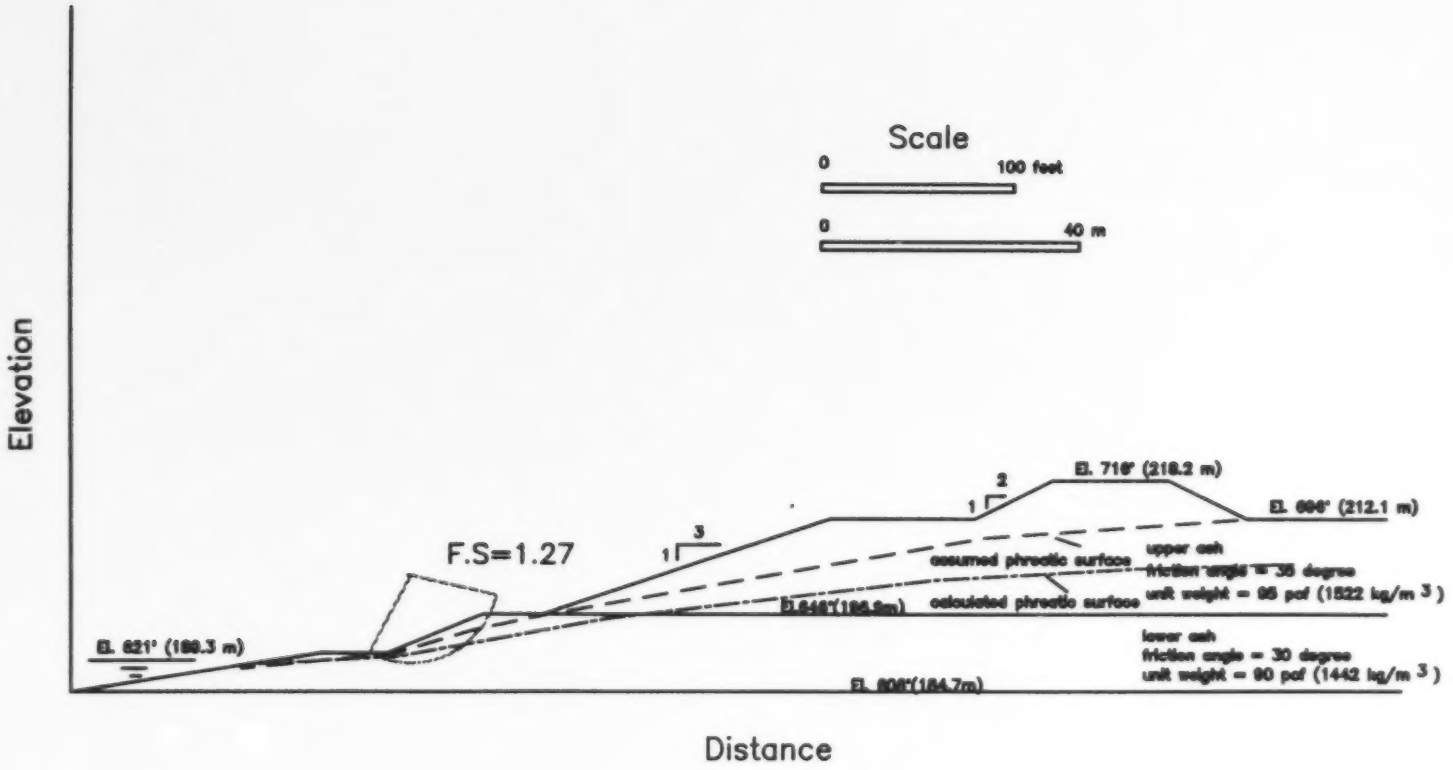


Figure 5 Design cross section of the existing ash storage mound – Section S4.



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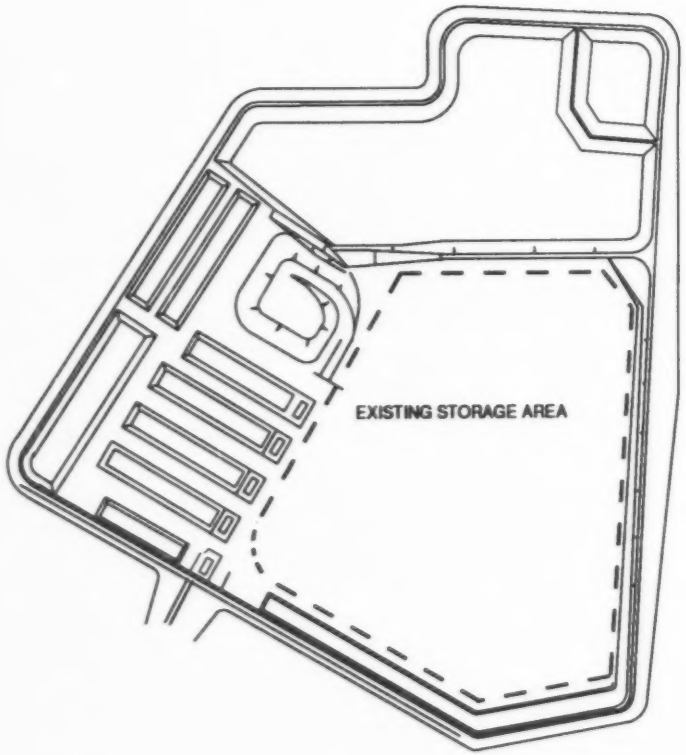


EXISTING ASH STORAGE SCHEME - WET DISPOSAL METHOD

PROPOSED ASH STORAGE SCHEME - DRY DISPOSAL METHOD

**FIGURE 6**

**COMPARISON BETWEEN THE EXTENTS OF THE EXISTING AND THE PROPOSED ASH STORAGE SCHEMES**

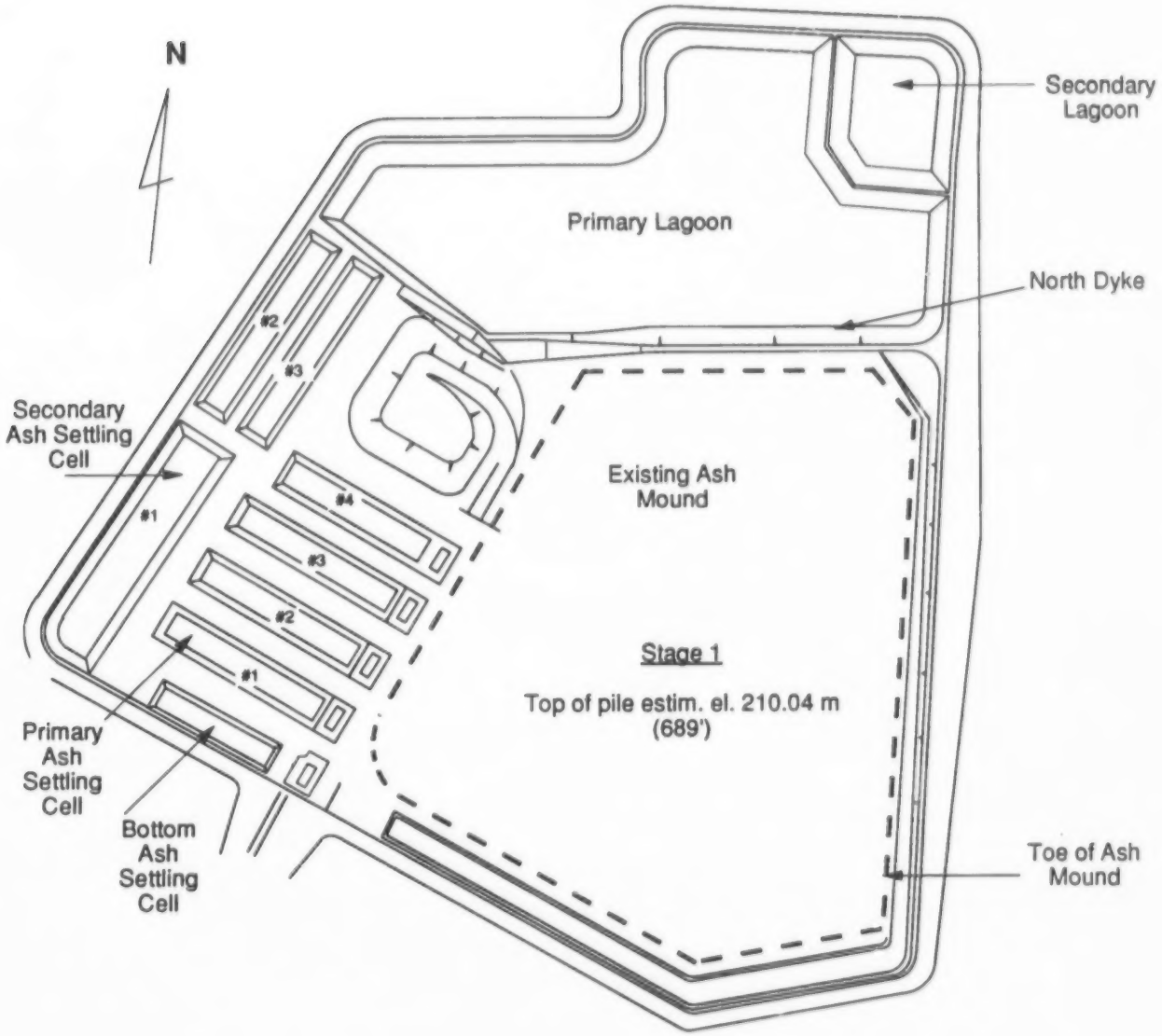


**FIGURE 7**

**LAYOUT OF THE EXISTING ASH STORAGE MOUND - STAGE 1**

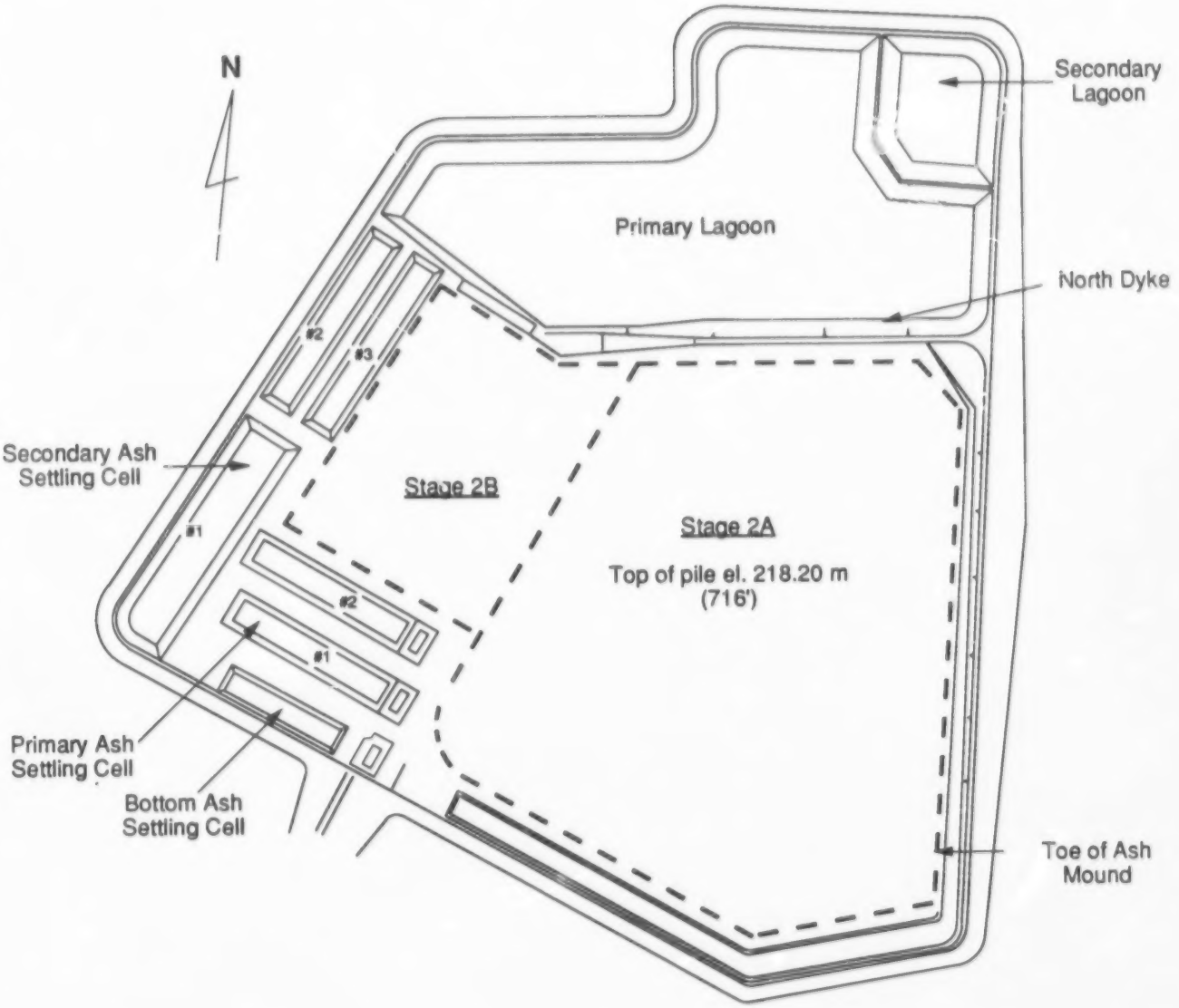


**FIGURE 8**

**LAYOUT OF THE ASH STORAGE MOUND - STAGE 2**

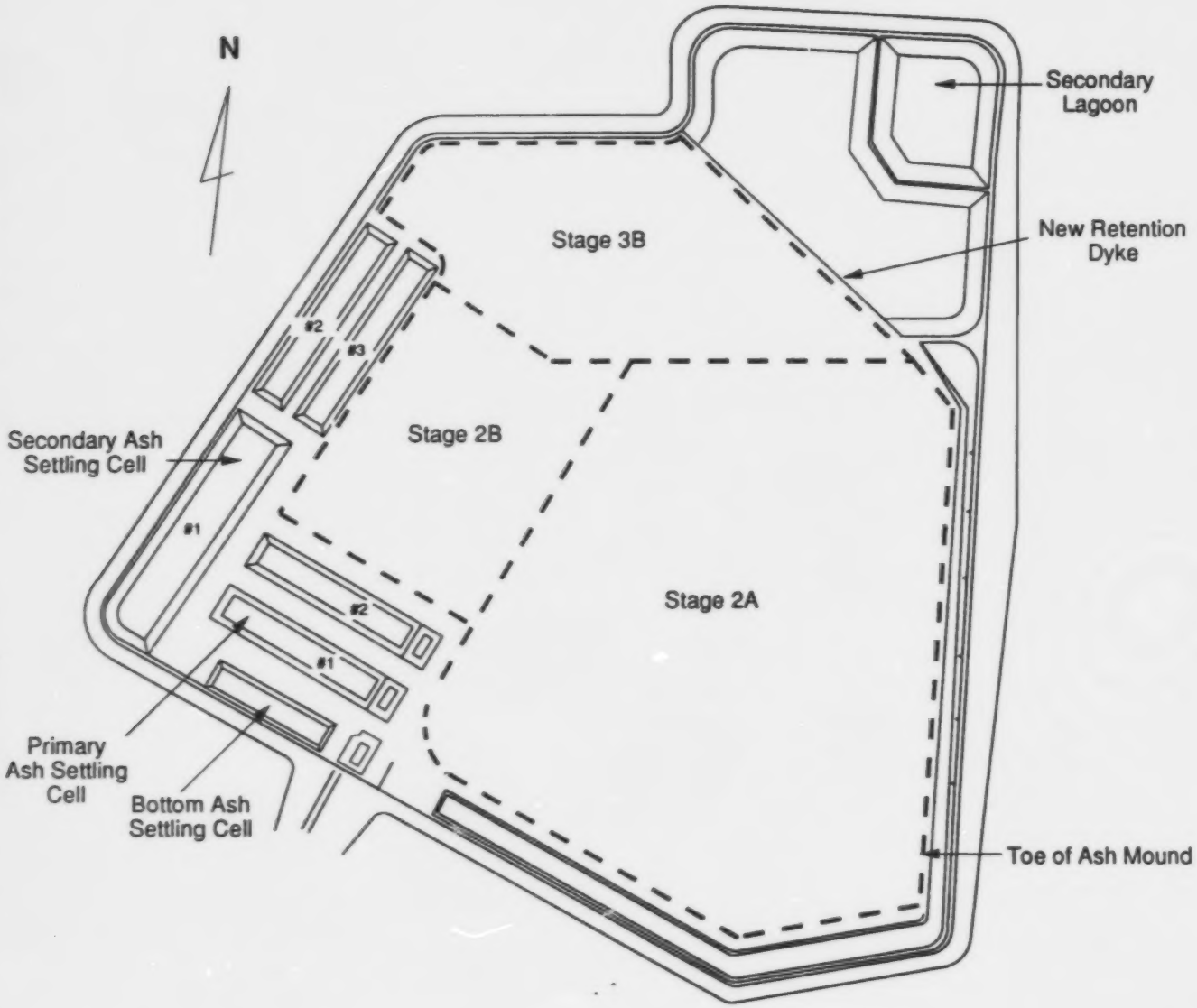


**FIGURE 9**

**LAYOUT OF THE ASH STORAGE MOUND - STAGE 3**

180723-C11-RD

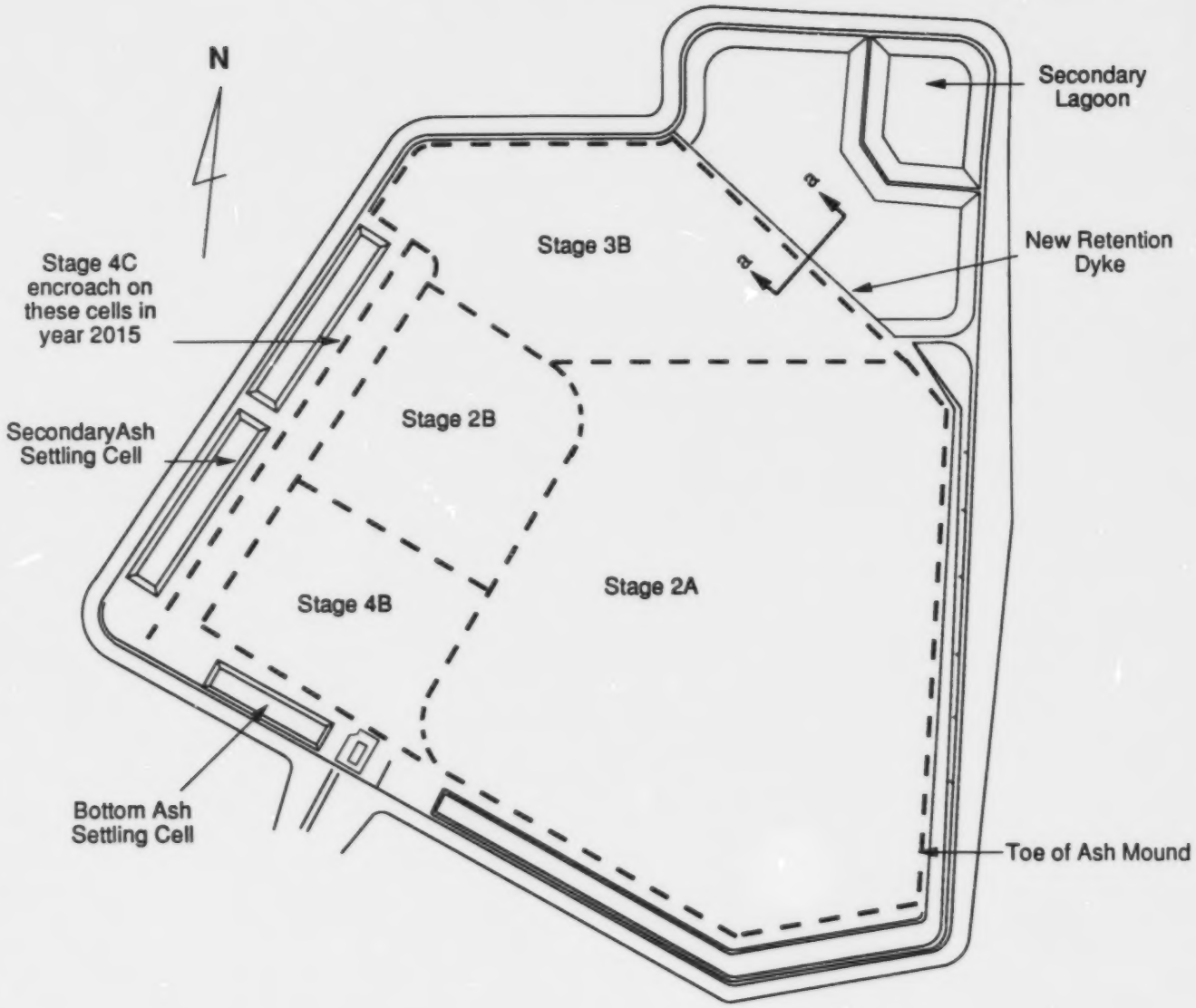


**FIGURE 10**

**LAYOUT OF THE ASH STORAGE MOUND - STAGE 4**

Locations of failure surface

| | Friction angles of the clay layer, degree | | |
|---|---|---|---|
| Phreatic surface | 15 | 20 | 25 |
| 203.29 m | type 1 | type 1 | type 1 |
| 197.19 m | type 1 | type 1 | type 2 |
| 189.27 m | type 1 | type 1 | type 2 |

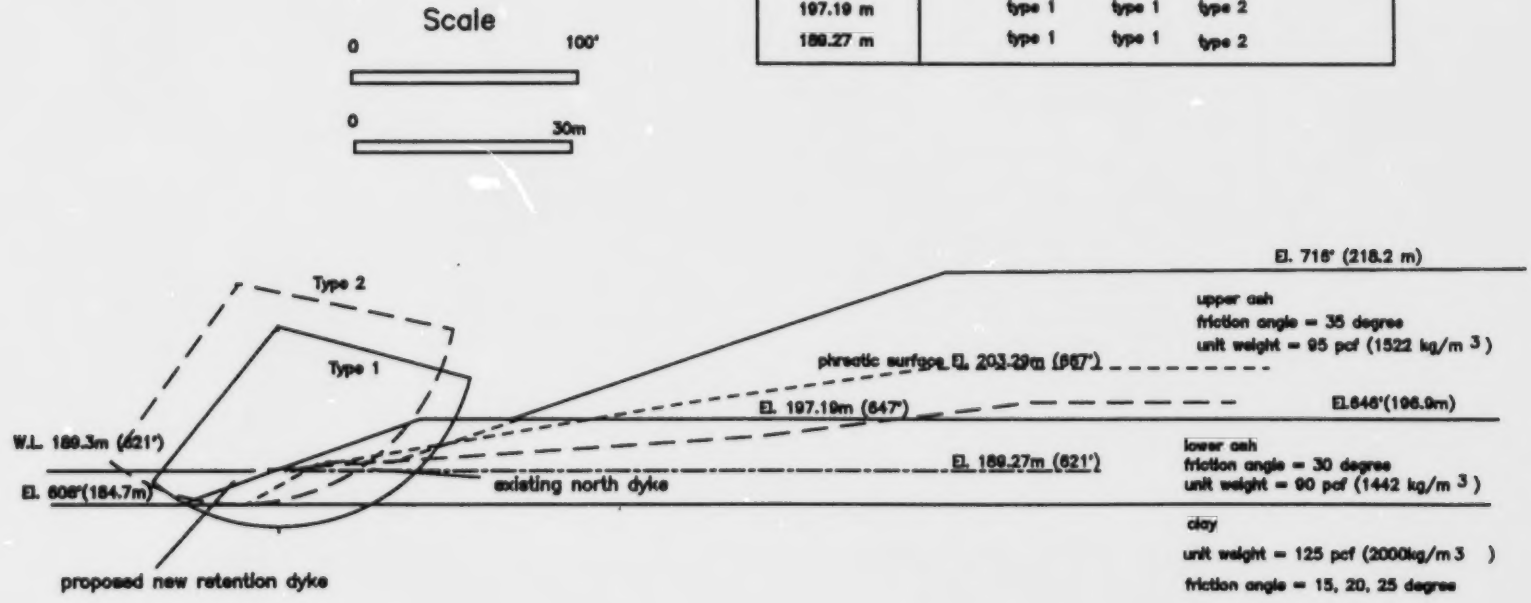


Figure 11 Stability of section a–a.

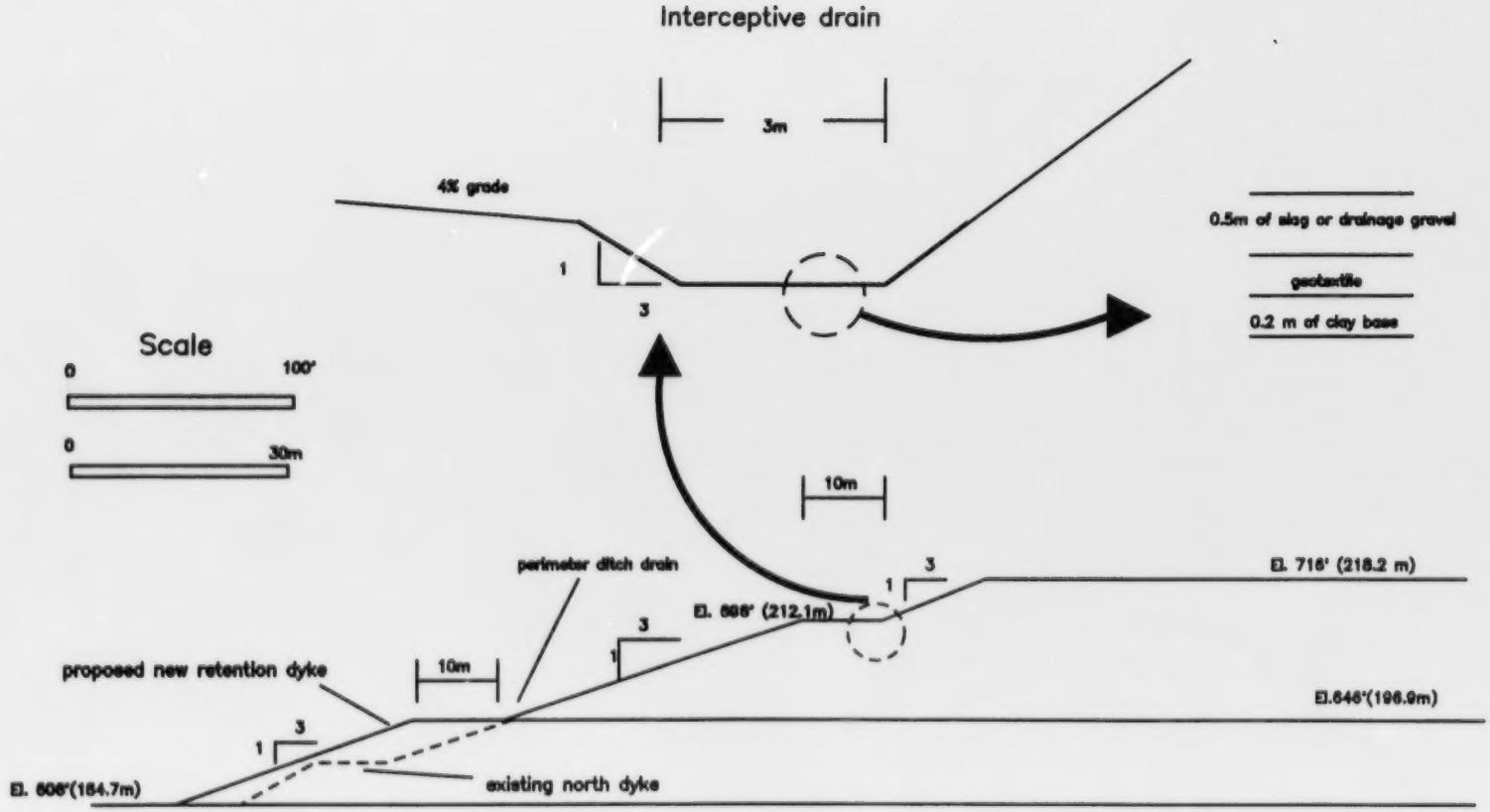


Figure 12 Proposed design geometry of the ash mound.

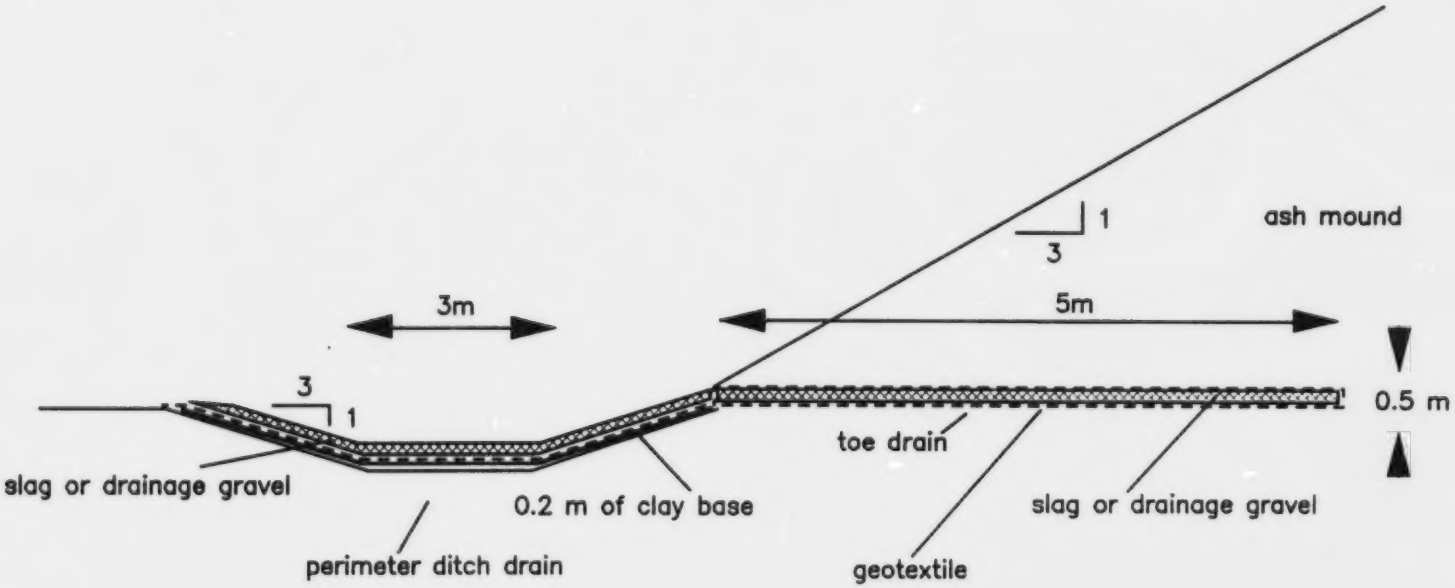


Figure 13 Proposed design of the toe drain and the perimeter ditch drain.

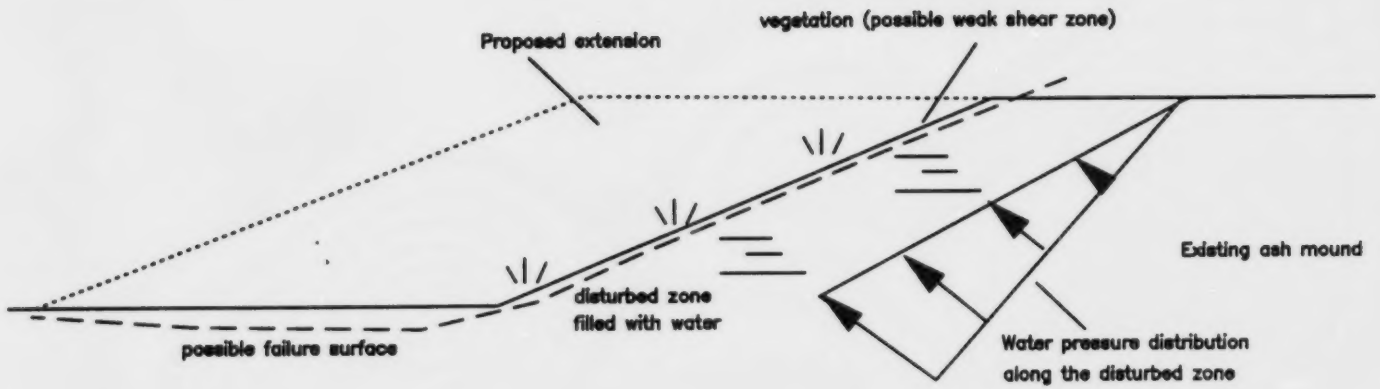


Figure 14 Schematic diagram showing the potential problems at the contact zone.

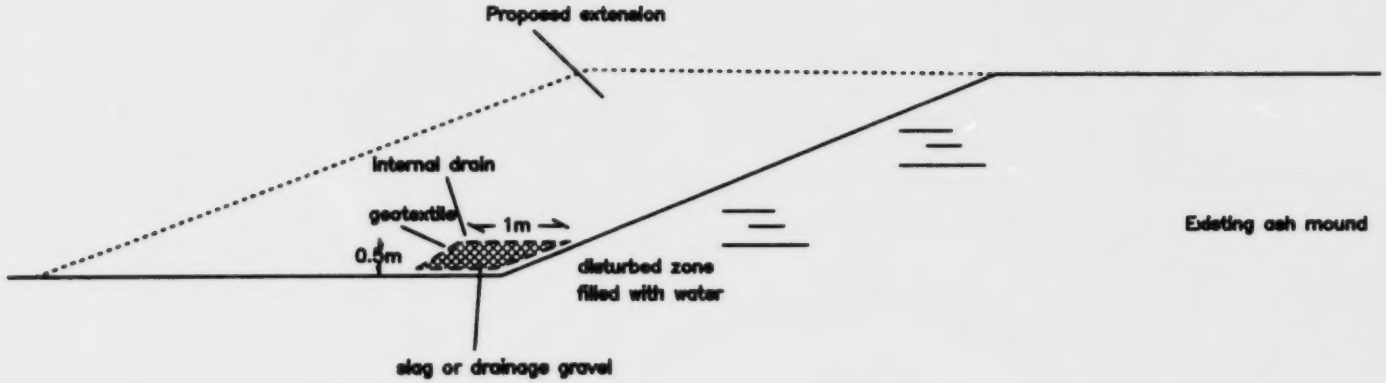


Figure 15 Layout and design of the internal drain.

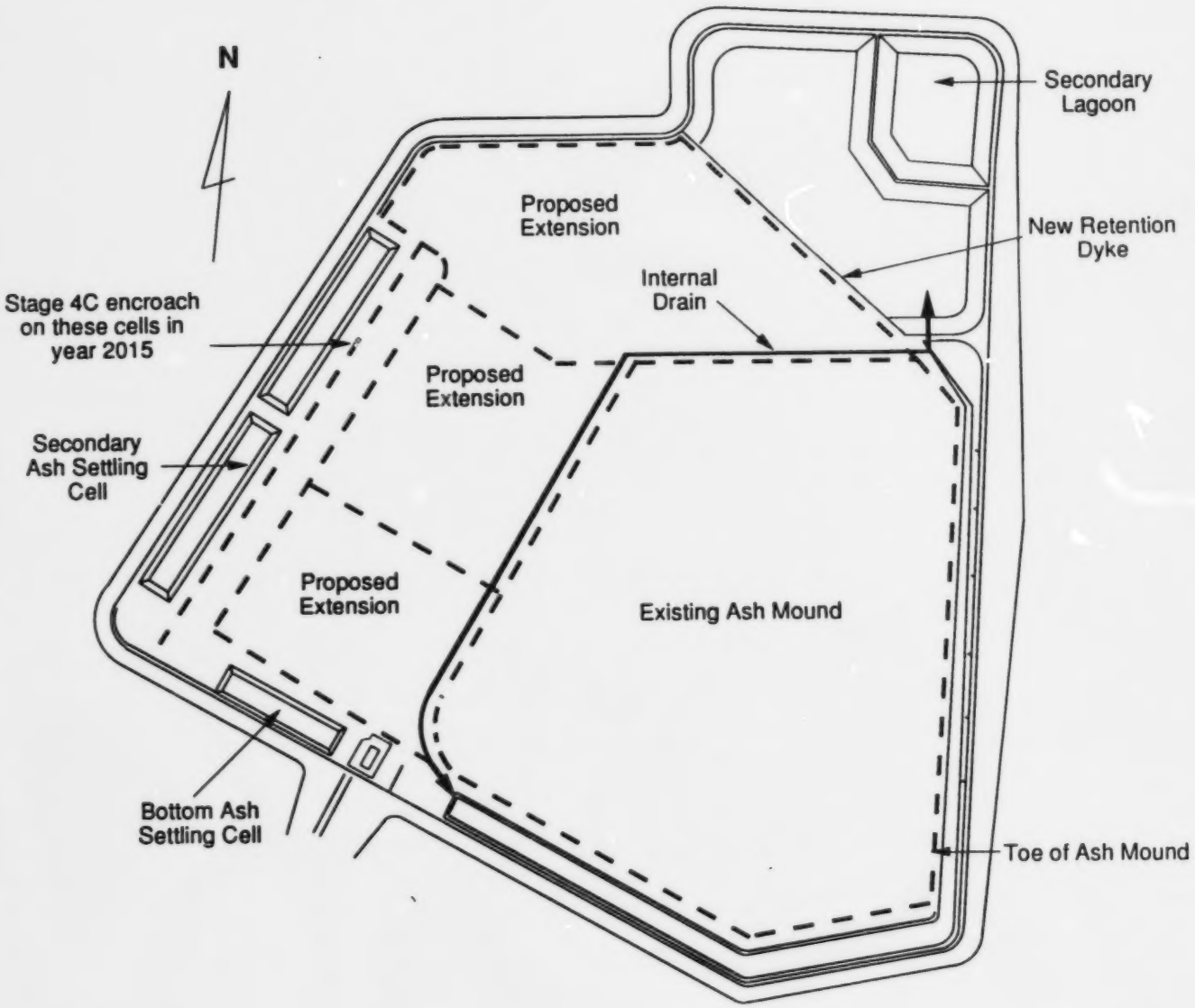


**FIGURE 16**

**LAYOUT AND DESIGN OF THE INTERNAL DRAIN**

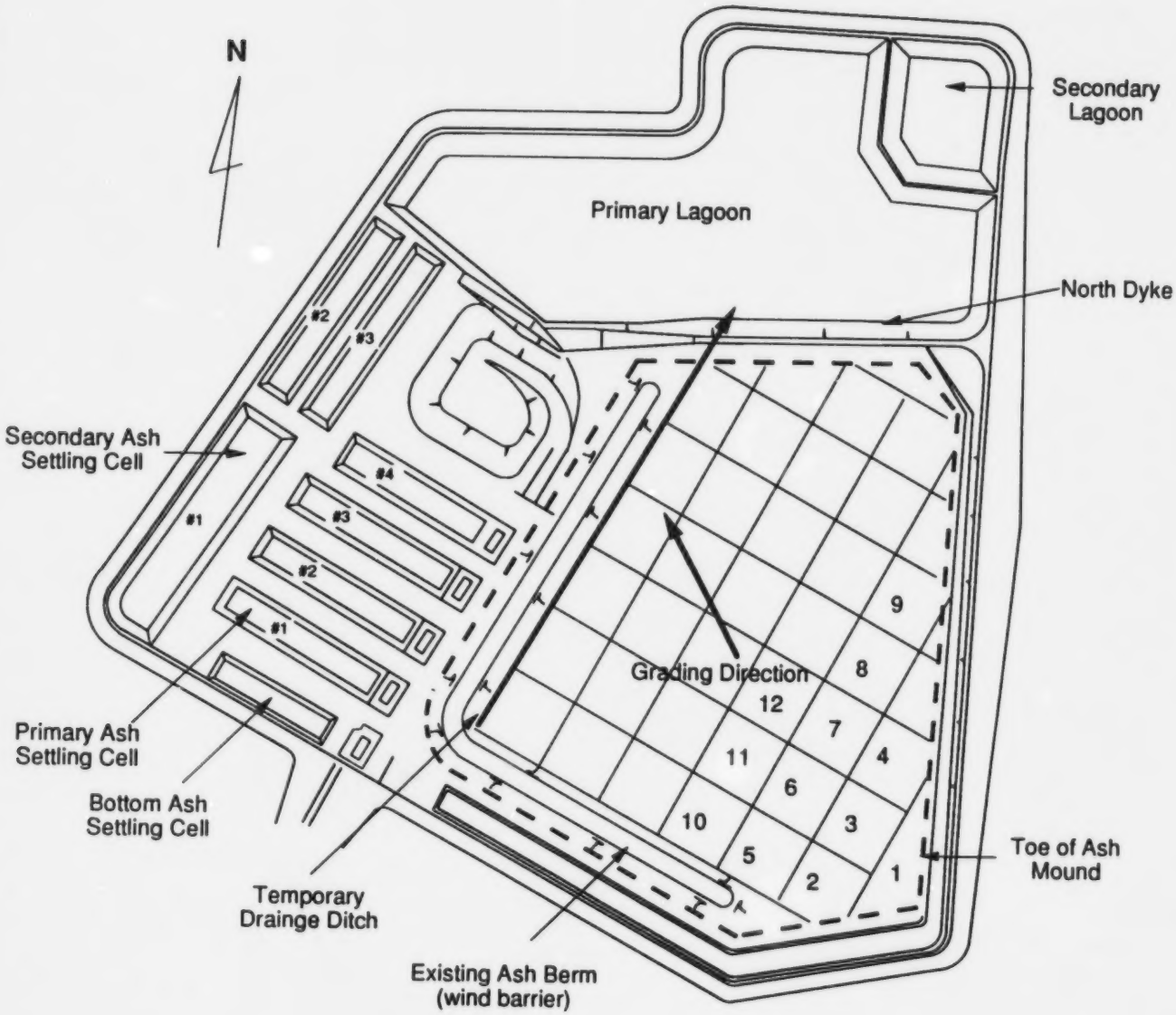


**FIGURE 17**

**LAYOUT OF THE CELL UNITS AND THE WIND BARRIER - STAGES 1 AND 2A**

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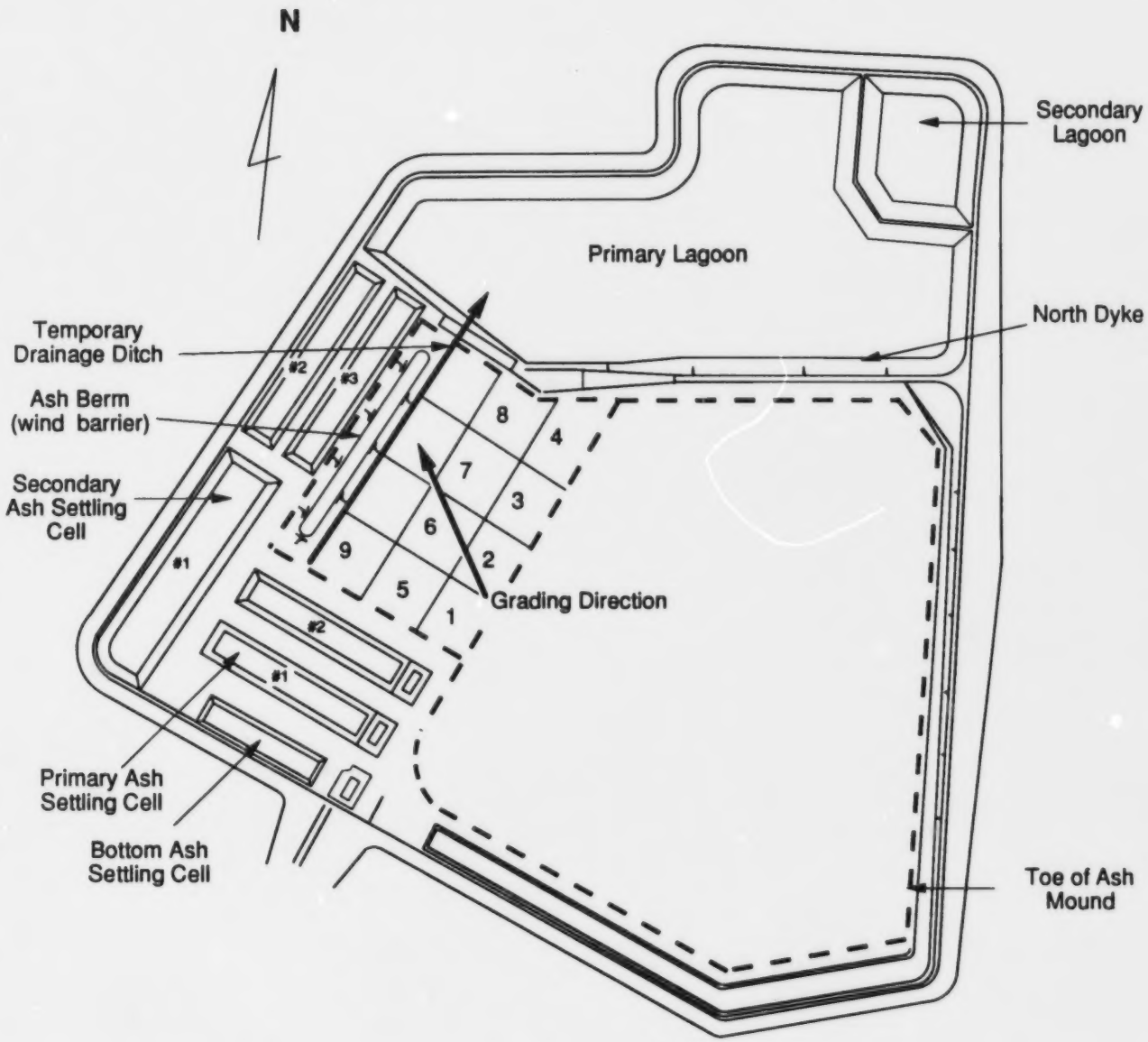


**FIGURE 18**

**LAYOUT OF THE CELL UNITS AND THE WIND BARRIER - STAGE 2B**

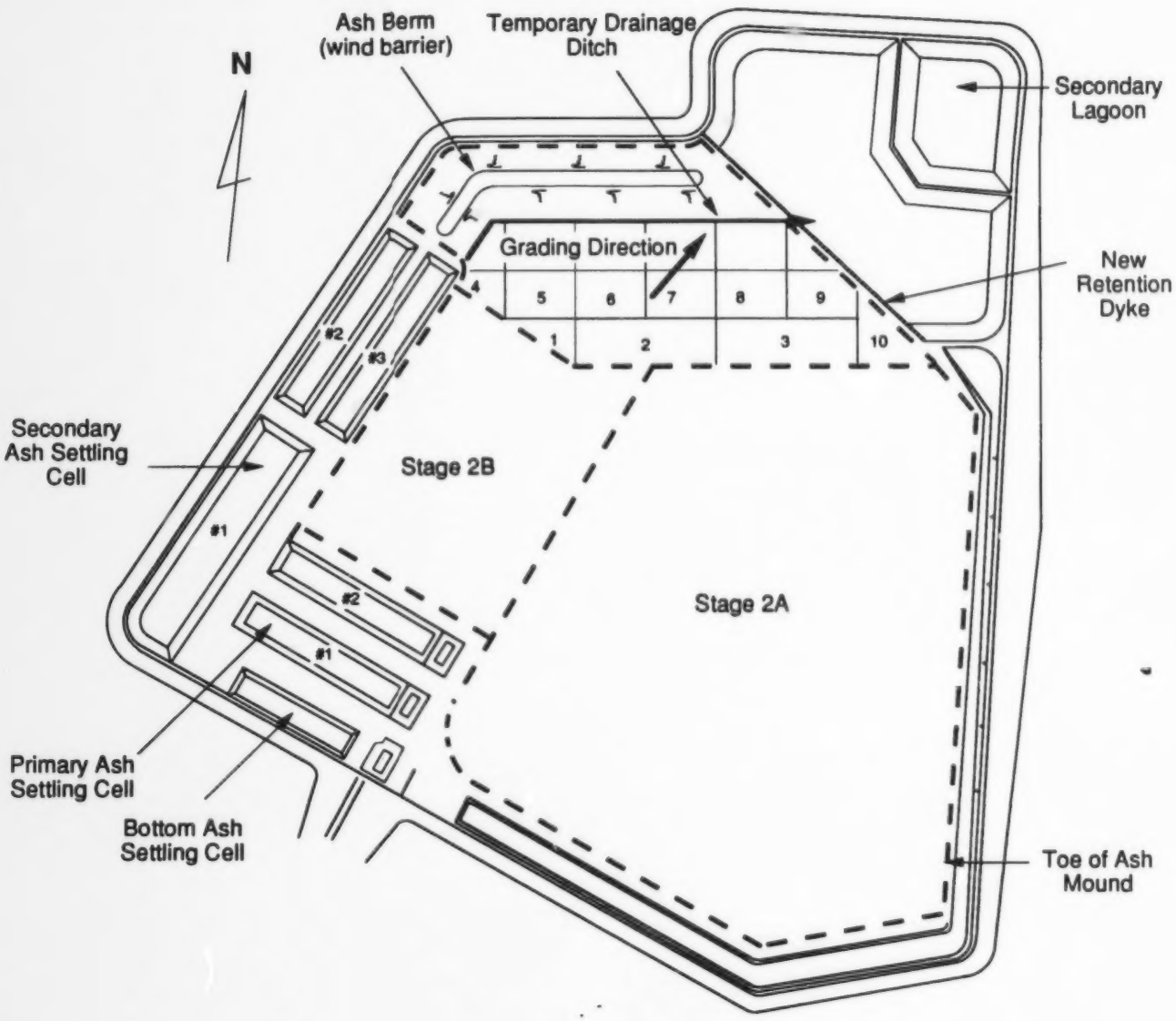


**FIGURE 19**

**LAYOUT OF CELL UNITS AND THE WIND BARRIER - STAGE 3**

180730-C11-RD

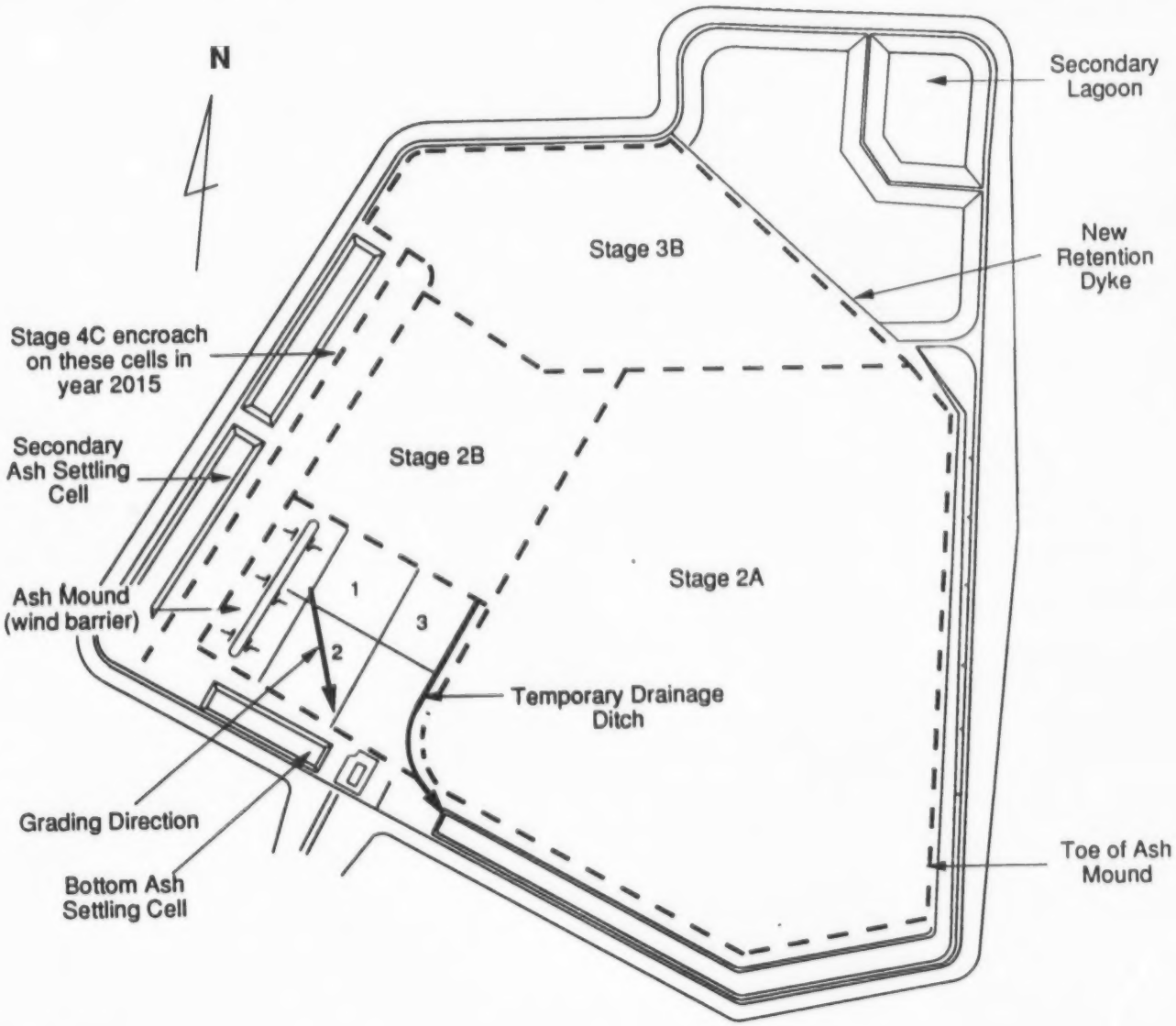


**FIGURE 20**

**LAYOUT OF THE CELL UNITS AND THE WIND BARRIER - STAGE 4**

180731-C11-RD

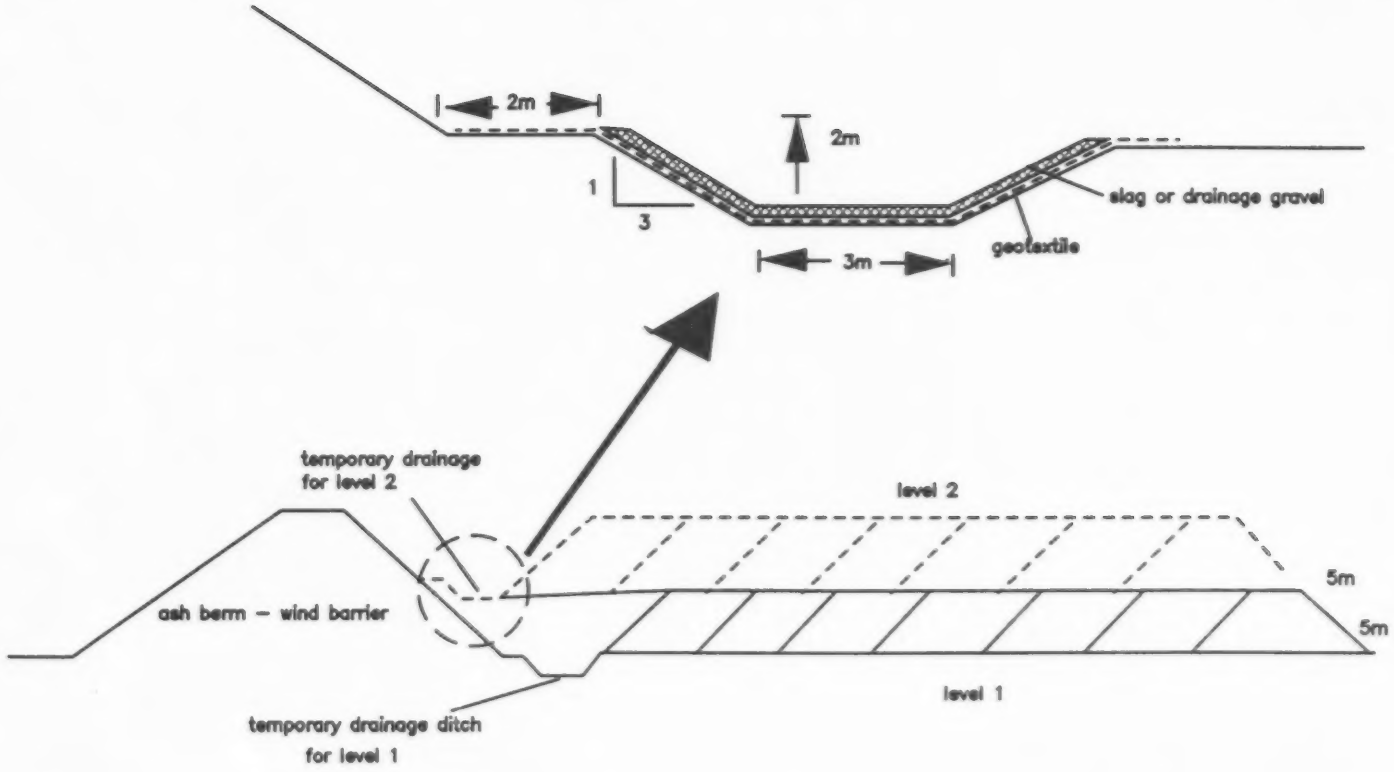


Figure 21 Design of temporary drainage ditch.

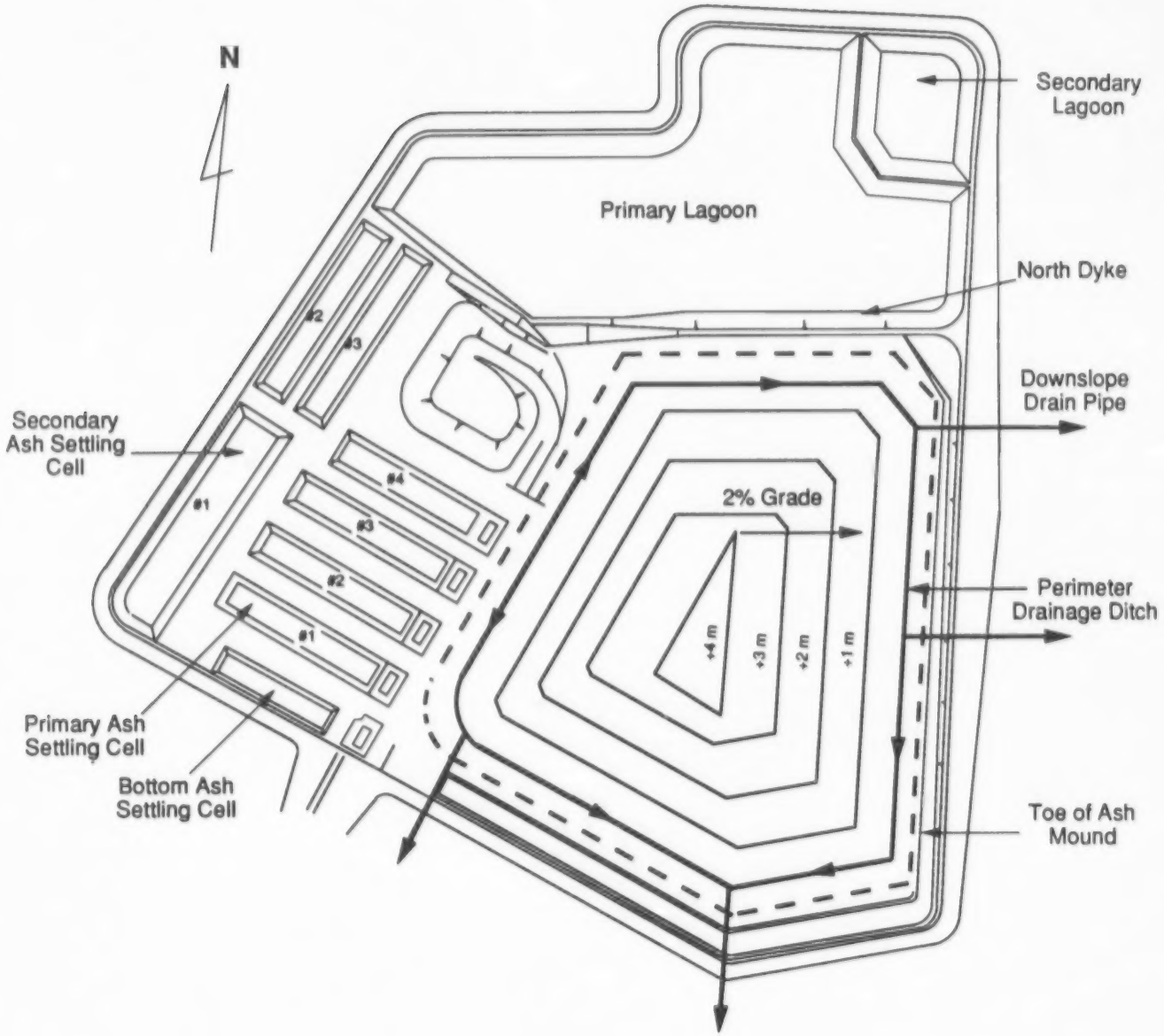


**FIGURE 22**

**LAYOUT OF THE PERIMETER DRAINAGE DITCH AND SURFACE GRADING - END OF STAGE 2A**

180734-C11-RD

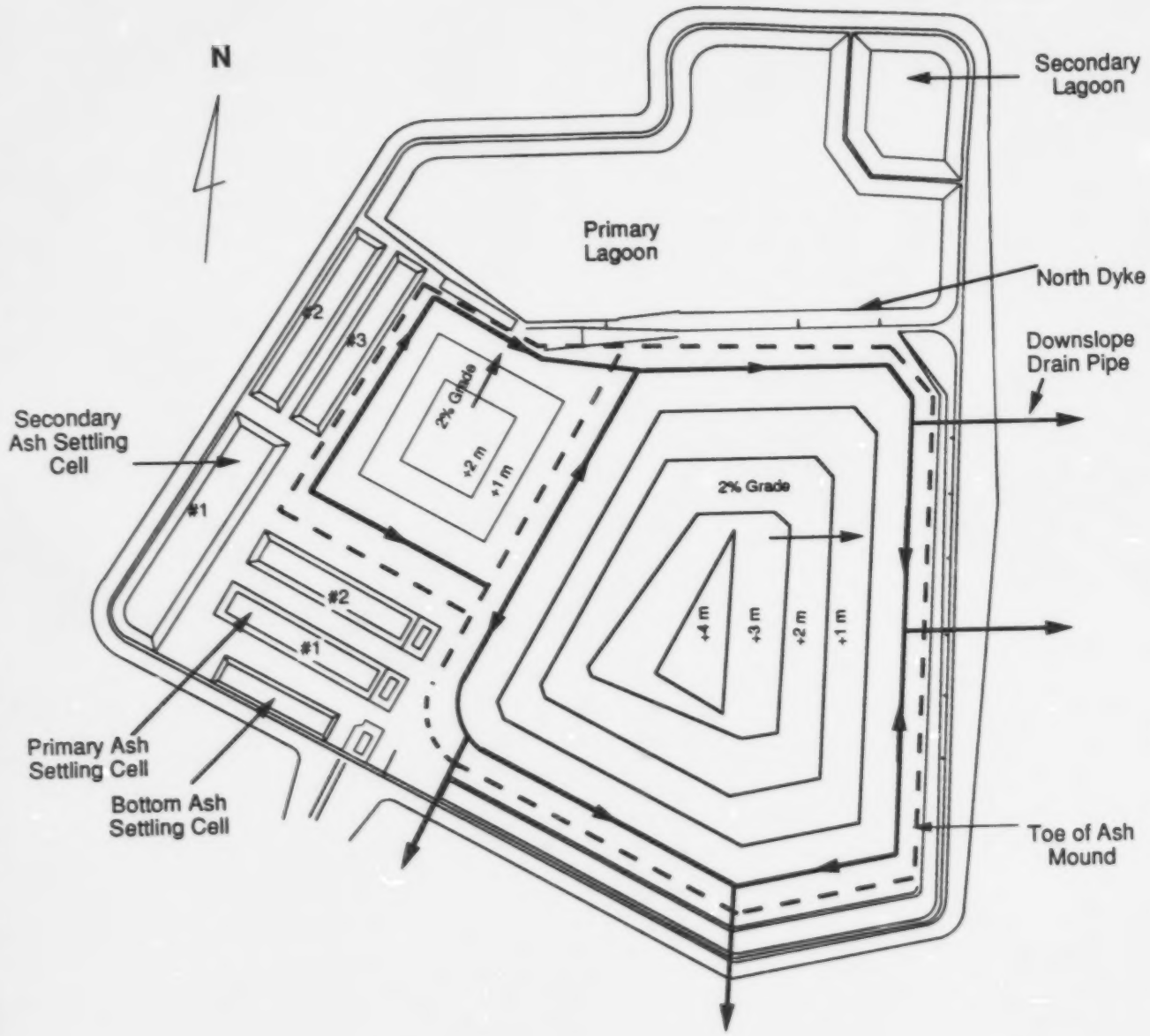


**FIGURE 23**

**LAYOUT OF THE PERIMETER DRAINAGE DITCH AND SURFACE GRADING - END OF STAGE 2B**

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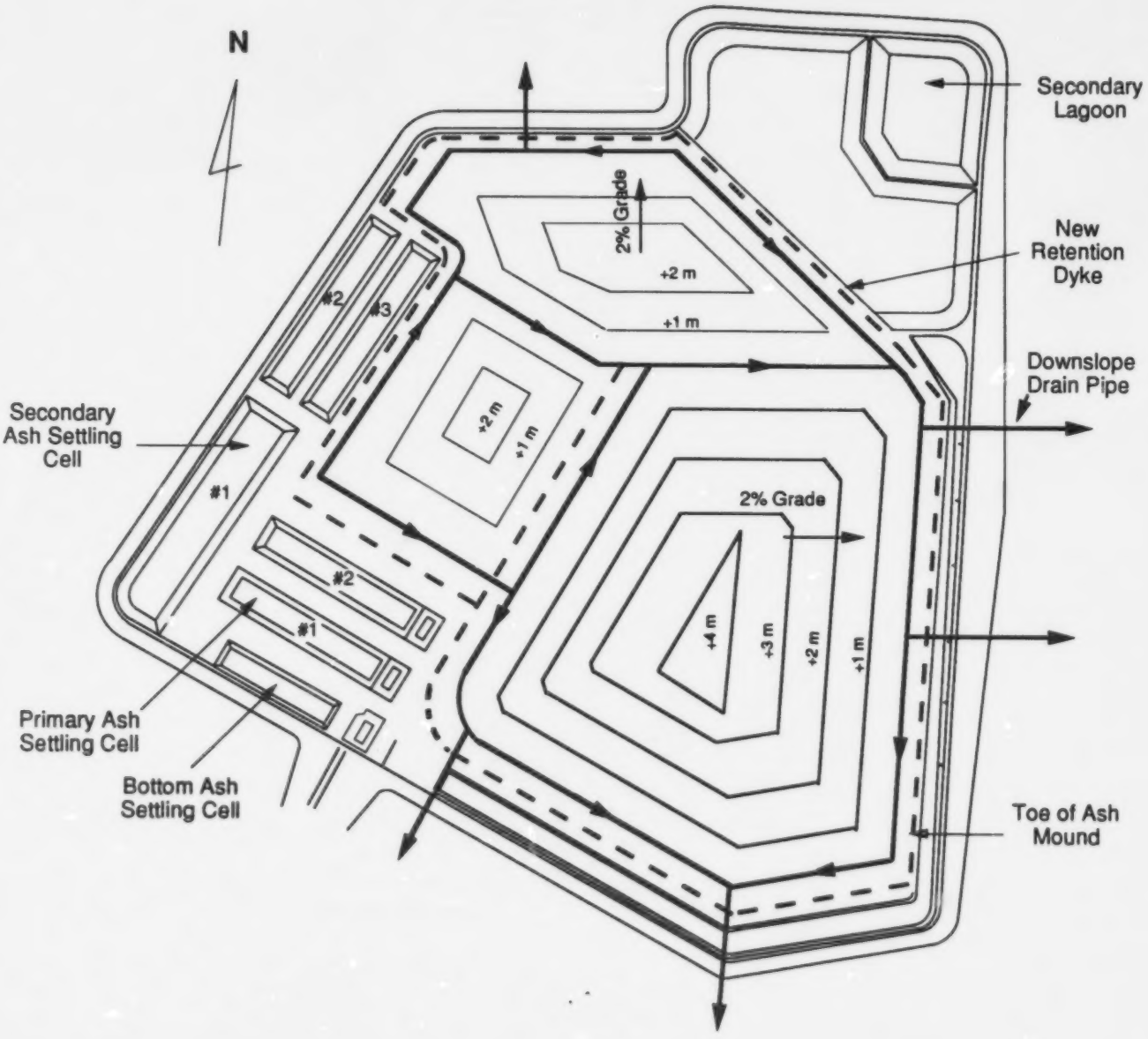


**FIGURE 24**

**LAYOUT OF THE PERIMETER DRAINAGE DITCH AND SURFACE GRADING - END OF STAGE 3**

180735-C11-RD

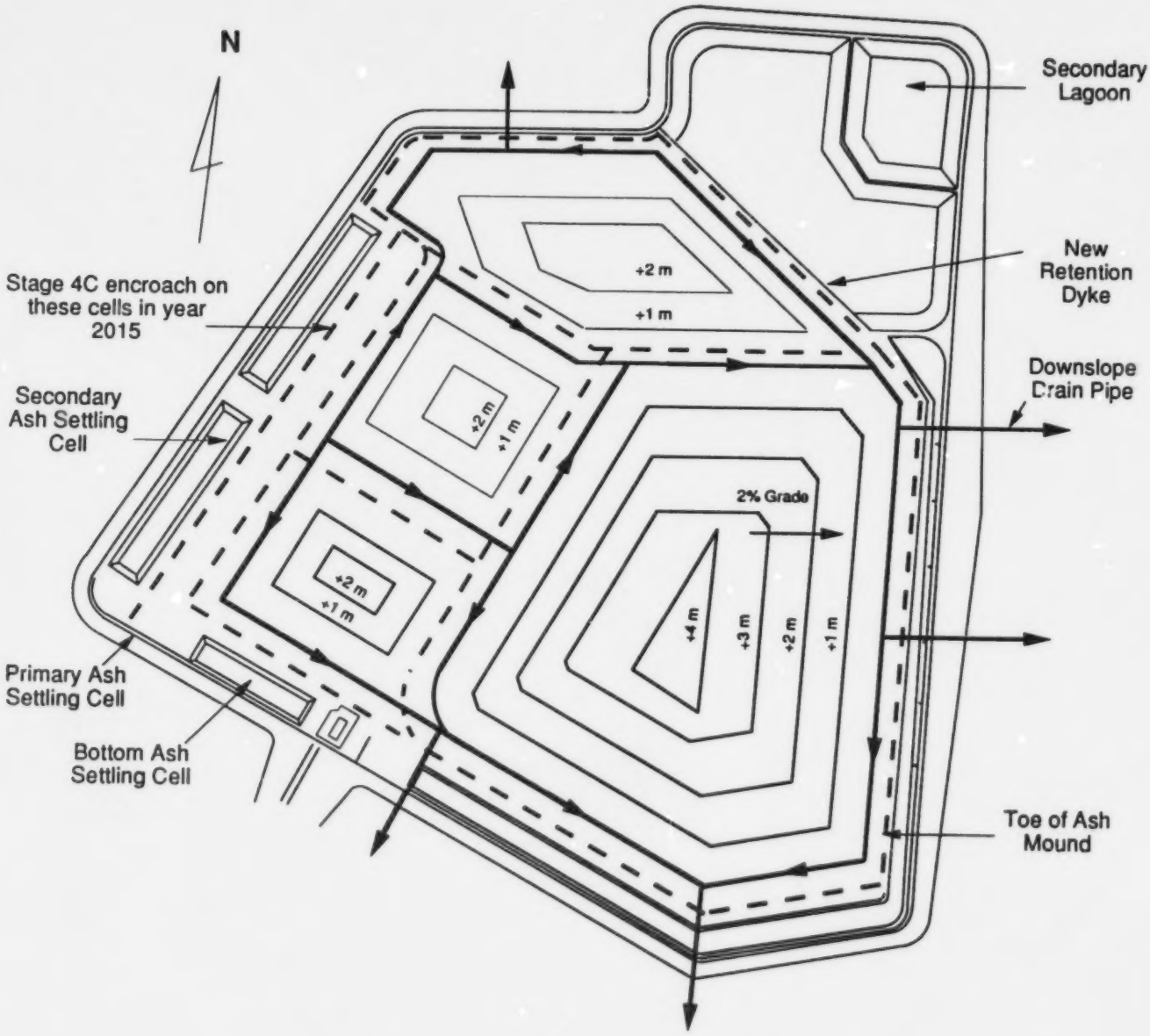


**FIGURE 25**

**LAYOUT OF THE PERIMETER DRAINAGE DITCH AND SURFACE GRADING - END OF STAGE 4**

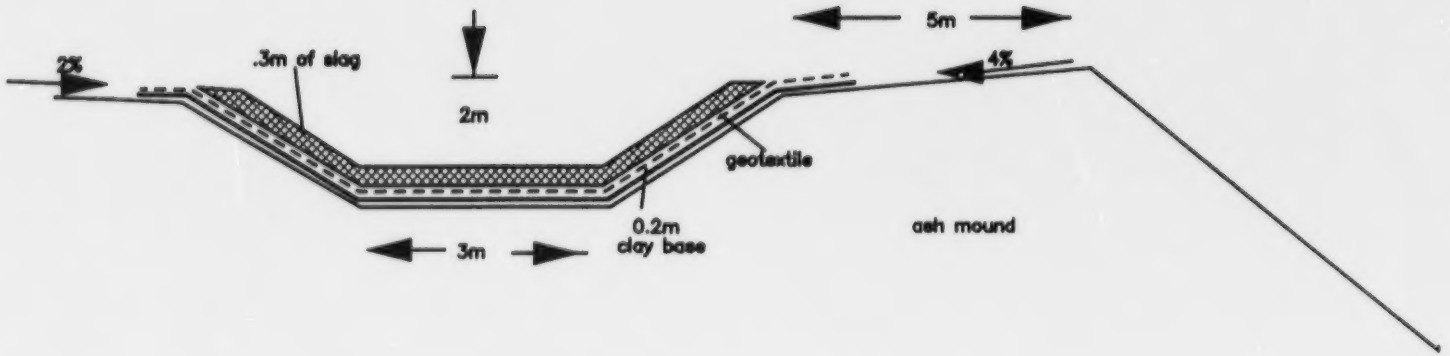


Figure 26 Design of the final perimeter drainage ditch.



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Locations of failure surface

| | Friction angles of the clay layer, degree | | |
|---|---|---|---|
| Phreatic surface | 15 | 20 | 25 |
| 203.29 m | type 1 | type 2 | type 3 |
| 197.19 m | type 1 | type 2 | type 3 |

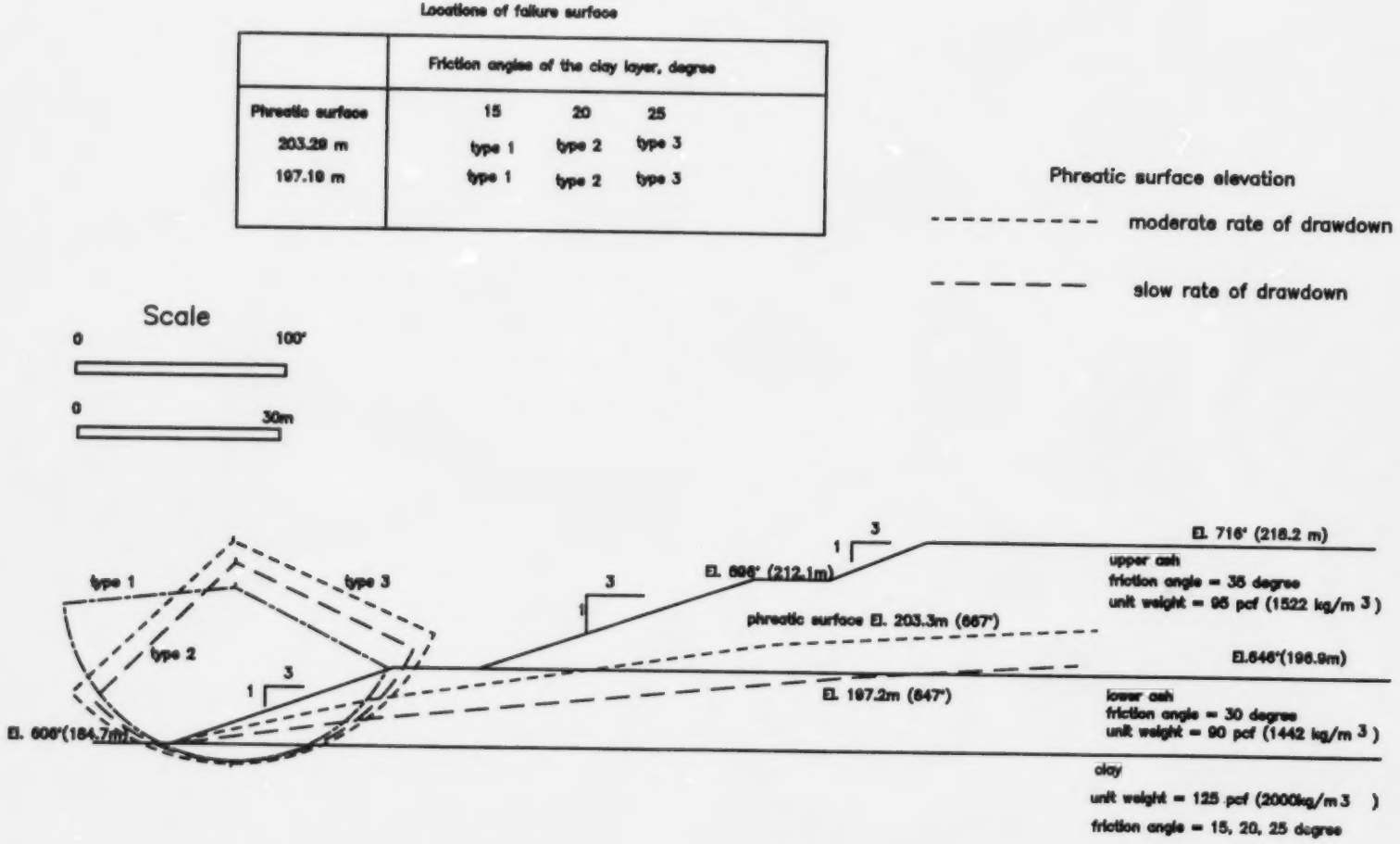


Figure 27 Stability of the ash mound during different drawdown conditions.

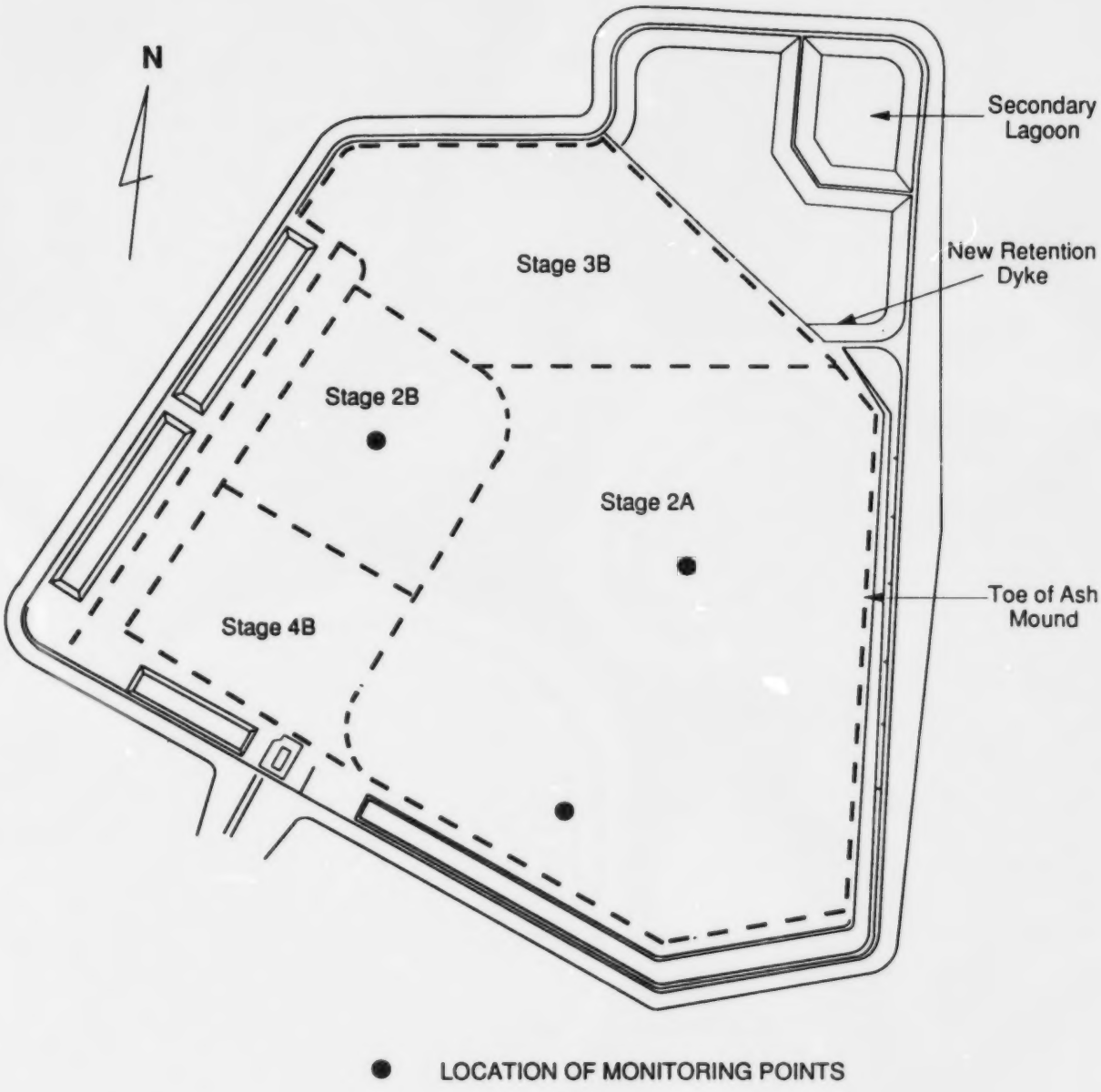


**FIGURE 28**

**LOCATION OF THE MONITORING SYSTEMS**

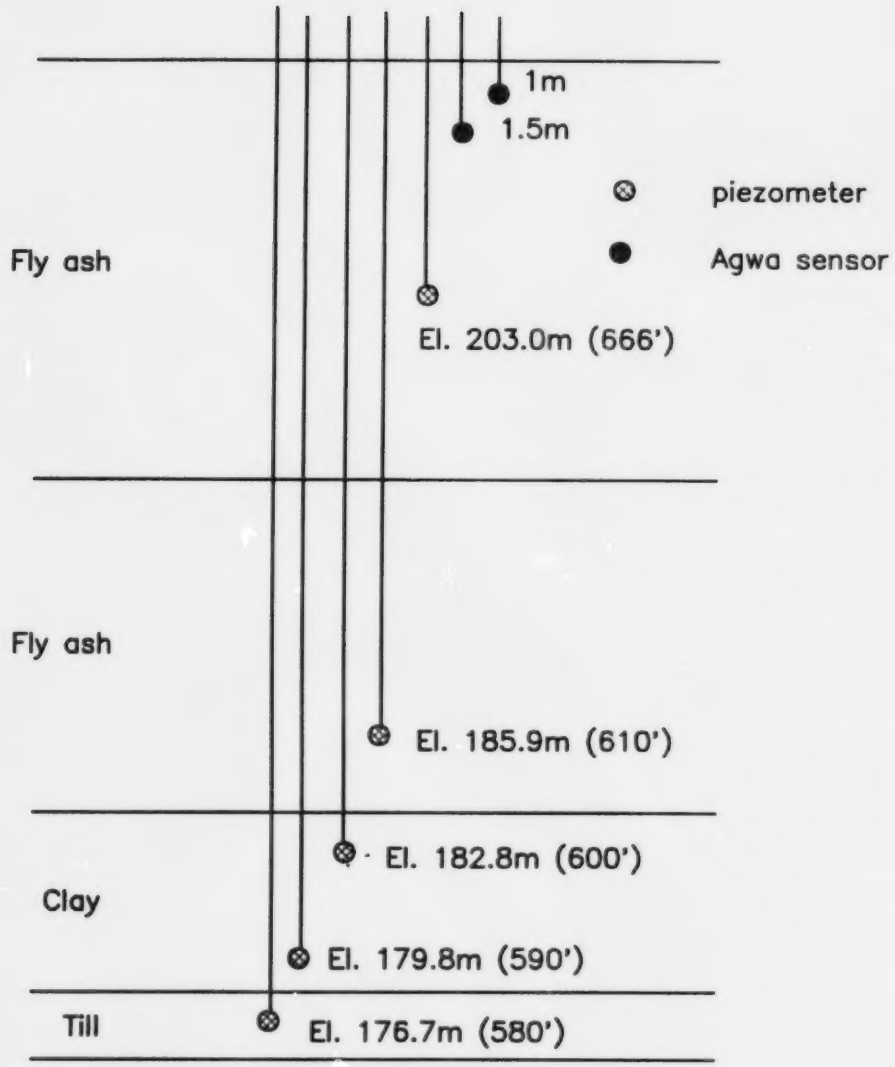


Figure 29 Layout of piezometers and Agwa sensors.